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EDITA IUSSU SOCIETATUM RADIOLOGICARUM
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THE OVARIAN ARTERY

An Arteriographic Study in Human Subjects

by

Ulf Borell and *Ingmar Fernström*

According to Dos Santos (1931) the ovarian artery is rarely shown in aortography. Only two films in which this was achieved are reproduced in his monograph. One of these was taken in a case of myoma, and the other in a case of pregnancy at the 6th month. Gesenius (1952) described a case of thrombosis of the aorta examined by aortography in which the ovarian artery was seen to take part in the collateral circulation to the pelvis and the lower extremities, and showed up well because its calibre was increased. These are the only cases published in the literature, to the best of our knowledge, in which visualization of the ovarian artery was obtained by arteriography *in vivo*.

In a previous paper the blood supply of the adnexa was investigated by pelvic arteriography and demonstration of the uterine artery (Borell and Fernström 1953). The view was expressed in that paper that radiologic visualization of the ovarian artery might be of aid in the diagnosis of adnexal tumours in those cases where the uterine artery is not seen to send branches to the adnexa.

The present investigation was carried out 1) to ascertain the percentage of cases in which visualization of the ovarian artery can be achieved by aortography, 2) whether its radiologic demonstration opens up new diagnostic possibilities with special reference to the diagnosis of adnexal tumours.

The ovarian artery was visible in the films in 22 of the 77 cases included in this investigation. In view of the paucity of cases published in which opacification of the ovarian artery was obtained *in vivo* by arteriography, these cases were considered worthy of publication.

Submitted for publication, April 20, 1954.

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The Anatomy of the Ovarian Artery

Point of origin. According to the literature the ovarian artery generally arises from the frontal aspect of the aorta. Only in 6 to 12 per cent of cases has it been found to originate from the renal artery, and then usually from the right (GÉRARD 1913; HASELHORST et al. 1926; JOACHIMOVITS 1931). In 1 per cent of cases it has been found to arise as a single artery dividing into two branches shortly after its origin (GÉRARD 1913; JOACHIMOVITS 1931). The point of origin of the ovarian artery appears to be situated within a relatively circumscribed area of the aorta. According to LUSCHKA (1864) its origin lies 6 cm proximal to the bifurcation of the aorta. GÉRARD (1913) has reported that it is situated 2 to 35 mm below the commencement of the superior mesenteric artery. According to HASELHORST et al. (1926) the ovarian artery arises between the lower portion of the first and third lumbar vertebrae, generally on a level with the second lumbar vertebra. In rare cases the point of origin of the ovarian artery has been found to be situated below the bifurcation of the aorta. ADACHI (quoted from JOACHIMOVITS 1931) reported such a case in which the ovarian artery was found to arise from the common iliac artery. In 2 to 10 per cent of cases two ovarian arteries have been found to arise on one or both sides (GÉRARD 1913; JOACHIMOVITS 1931).

Course of the ovarian artery. It has been reported that the ovarian artery generally forms a relatively wide angle with the aorta at its point of origin (HASELHORST et al. 1926). According to NAGEL (1897) and FREDET (1899) the ovarian artery follows first a straight course, becoming slightly tortuous on reaching the true pelvis.

Width of the ovarian artery. JOACHIMOVITS (1931) and MASSABUAU et al. (1936) have reported that the calibre of the ovarian artery is smaller than that of the uterine artery. According to LUSCHKA (1864) the calibre of the ovarian artery increases markedly in pregnancy. He believed that the ovarian artery contributes to the blood supply of the pregnant uterus.

Distribution of the ovarian artery. The ovarian artery and the adnexal branches of the uterine artery take part in the blood supply of the tube and the ovary. The ovarian artery generally supplies the lateral third of the tube and the lateral half of the ovary, but its distribution shows great variation (FREDET 1899; DUBREUIL-CHAMBARDEL 1925—26; DIEULAFÉ et al. 1935; MASSABUAU et al. 1936; MOCQUOT et al. 1938). In rare cases it has been found to supply only a small portion of the adnexa or no part of these organs. BROEKAERT (1892) believed that this was the rule and not an exception and therefore argued against the view that the ovarian artery plays án important rôle in the blood supply of

the adnexa. According to other workers, however, the ovarian artery is materially concerned in the blood supply of these organs, and also takes part in the blood supply of the fundus uteri (LUSCHKA 1864; HYRTL 1873; SOULIGOUX 1894; REDLICH 1909). The tubal and ovarian blood supply and the variations which may occur, were discussed in a previous paper (BORELL and FERNSTRÖM 1953).

Method

A catheter was inserted percutaneously into the femoral artery ad modum SELDINGER (1953). The catheter was generally introduced so that its tip lay just below the bifurcation of the aorta. Pelvic arteriography was then carried out to obtain visualization of the uterine artery. Following this procedure the catheter was passed further up into the aorta so that its tip lay on a level with the second lumbar vertebra. 30 ml of Umbradil 70 % were then injected through the catheter. The instant the injection was completed three antero-posterior films were exposed at intervals of a few seconds (patient supine). Sixty-one cases were examined by this method. In a further 16 cases, a modification of this technique was employed, consisting of compression of the aorta just above its bifurcation during the injection of the contrast medium further up into the aorta. With this method the strength of the Umbradil solution was reduced to 50 per cent, and the quantities injected varied between 30 and 40 ml.

Cases Investigated

Of the 77 women included in this investigation 18 were at the menopause or post-menopausal, and 59 were of reproductive age.

In 22 of these 77 cases renal disease was suspected. These patients were examined by aortography alone. They were included in this investigation because the proximal portion of the ovarian artery is occasionally visible on the aortogram. In the other 55 cases the following pathologic conditions were present: Ovarian tumour — 12 cases; salpingitis — 3 cases; tubal pregnancy — 5 cases; incomplete abortion — 2 cases; metrorrhagia — 4 cases; myoma — 6 cases; anomaly of the reproductive organs — 2 cases; prolapse of the uterus — 1 case; oligomenorrhoea — 1 case; intestinal adhesions — 1 case; arteriosclerosis — 1 case. In 12 cases there was an intra-uterine pregnancy, and in 5 cases there was abdominal pain of unknown aetiology. All these 55 patients were examined by pelvic arteriography followed by aortography. In order to improve the quality of the films the field was limited to cover only the pelvis and the lower portion of the aorta in the second part of the examination. For this reason the point of origin of the ovarian artery was not included on the films. On the other hand, better visualization of its distribution in the true pelvis was obtained.

Results

Diagram 1 shows a representation of the course and the width of the ovarian artery in 5 of the 22 cases in which it was seen, together with the diagnosis established in these cases. The width was measured directly from the films at a point on a level with the 5th lumbar vertebra, and is given in mm. The measurements were made to an accuracy of 0.5 mm.

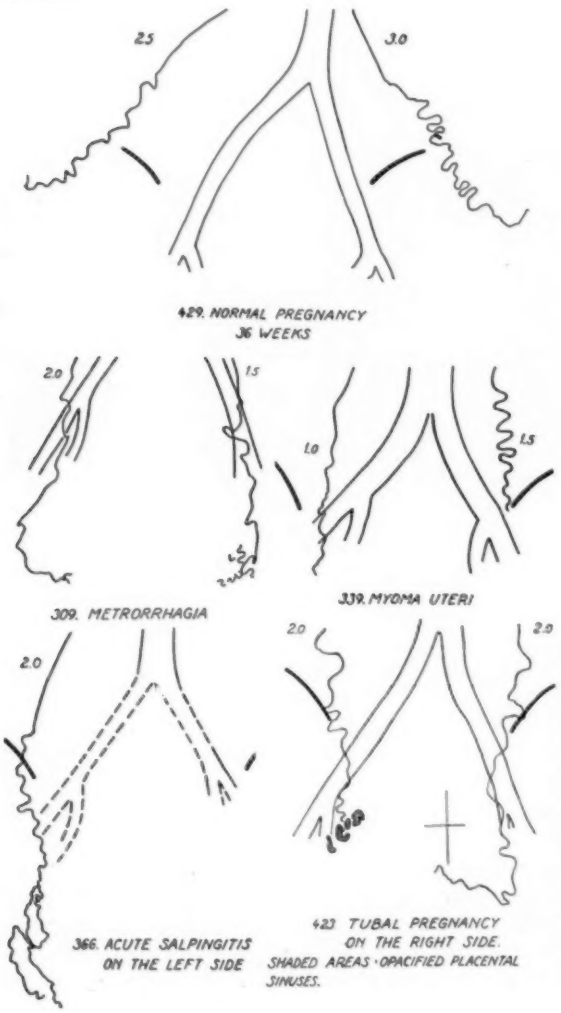
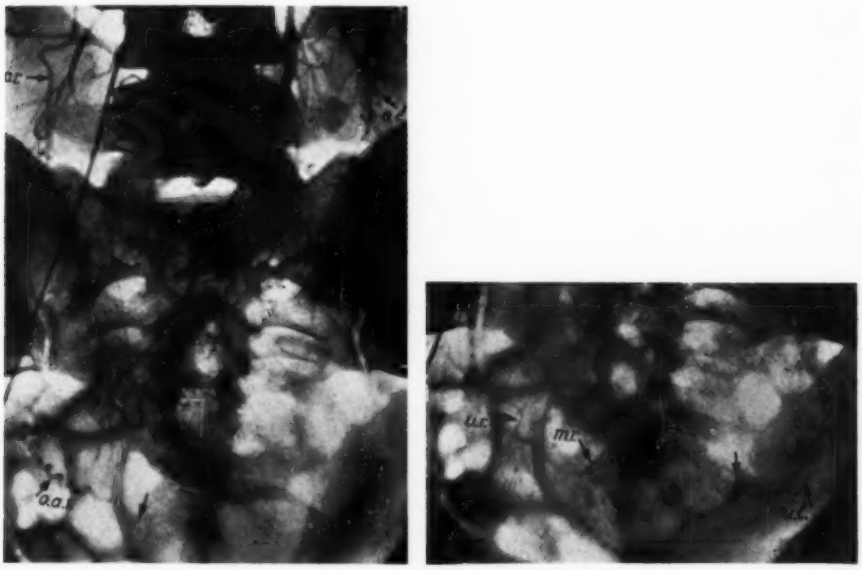


Diagram 1. Representation of the appearances of the ovarian arteries. Record numbers and diagnosis at the bottom, width of the ovarian artery in mm at the side of the drawings. Aorta and the iliac arteries are shown in a continuous line. Where aortic compression was applied, a broken line represents the appearance of the blood vessels just below the point of compression. Crista iliaca indicated by a thick line.

The course of the ovarian artery was found to be quite characteristic in all cases. It was generally seen to follow a straight or slightly wavy course for a short distance, becoming markedly tortuous on reaching the pelvic inlet.



a. b.

Fig. 1. Case of ovarian cyst, examined by aortography with satisfactory compression.

a. Immediately on completion of injection. o. r. = right ovarian artery; o. l. = left ovarian artery. Right ovarian artery anastomoses with the markedly tortuous ovarian arcade (o.a.r.). → The point where the ovarian artery reaches the uterus and anastomoses with the uterine artery.

b. A few seconds after a. Left side: the ovarian arcade stretched out by the cyst (o. a. l.). The point where the ovarian artery reaches the uterus and anastomoses with the uterine artery (→). Retrograde filling of the uterine artery in the parametrium (u. l.). Right side: relatively large number of intramural vessels (m. r.); uterine artery in the parametrium filled in a retrograde direction (u. r.).

In some cases it was difficult to identify the ovarian artery in the area where it runs over the sacrum or the os ilium on account of superimposed bony structure. In 16 cases the ovarian artery was visible as far as the region of the adnexa. In 4 of these it was seen to divide into two or three branches within the true pelvis which undoubtedly repre-

sented its adnexal branches (Diagram 1, record Nos. 309, 366, and Fig. 3).

In a further 4 cases there was no evidence of branching. In 3 of these, the contrast medium was seen to pass into the uterine artery which proved that filling of an adnexal branch had been obtained (Diagram 1, record No. 429).

Fig. 2.

Fig. 3.

Fig. 2. Normal spontaneous delivery two weeks prior to the examination. Aortography with compression. Only a small amount of contrast medium passed the point of compression. o. r., right ovarian artery; o. l., left ovarian artery. The upper portion of both ovarian arteries, particularly the right, is seen to be markedly tortuous (related to the recent pregnancy).

Fig. 3. A case of acute left-sided salpingitis, examined by aortography with unsatisfactory compression. The ovarian artery (o.r.) is seen to divide into two branches (r_1 and r_2) in the true pelvis which represent the ovarian and tubal arcade.

In the fourth case, in which there was a tubal pregnancy, filling of the placental sinuses was obtained by way of the ovarian artery (Diagram 1, record No. 423). In the remaining 8 cases the ovarian artery was visible as far as the true pelvis. However, it is impossible to say with certainty whether it was opaque as far as the adnexa.

In 6 of the 16 cases examined by *aortography with aortic compression*, the ovarian artery could not be seen. Two of these patients had an ovarian tumour, 2 had salpingitis, 1 had metrorrhagia, and 1 had a myoma. Four of these were of reproductive age, and 2 were post-menopausal. Three patients had borne children. In the remaining 10 cases visualization of the ovarian artery was obtained. All these patients were of reproductive age and had borne children.

Of the 61 cases examined by *aortography without aortic compression*, visualization of the ovarian artery was obtained only in 12 cases. Nine of these 12 patients were of reproductive age, and 3 were post-menopausal. Eight patients in this group were parous. It is interesting to note that in 2 of the post-menopausal cases the menopause had occurred 15 and 19 years previously, respectively. These 2 patients had no symptoms referable to a lesion of the reproductive organs. One of them had thrombosis of the aorta which may have accounted for the opacification of the ovarian artery, the ovarian artery probably serving as a collateral vessel.

In the other 49 cases the ovarian artery was not seen. Thirty-six of these patients were of reproductive age, and 13 were post-menopausal. Twenty of these 49 patients were parous and 10 patients were pregnant at the time of the examination. In 3 of the latter cases there was a tubal pregnancy.

According to the literature renal complications of arteriography are very rare. In a series of cases examined by abdominal aortography, injecting 30 ml of a 70 per cent solution of diodone, LARSSON and PALMLÖV (1952) checked renal function in a few cases by the urea clearance test, Heller's test, determination of the non-protein nitrogen level and urinary output, and by microscopy of the urine. Only in one of their cases, in which most of the contrast medium had been injected directly into the healthy kidney, did they note that the urea clearance was diminished for a few days after the examination. Judging from that investigation the risk of renal complications following aortography carried out without aortic compression appears to be small.

Compression of the aorta distal to the tip of the catheter may cause a relatively strong concentration of the contrast medium in the renal arteries and the injection of a large amount of contrast medium into these blood vessels, with possible risk of renal damage. In order to investigate this point the non-protein nitrogen level was determined and

Heller's test was carried out before and for a few days following the examination in several cases. In 1 case renal function was in addition checked by the water test.

A comparison was made between the findings in aortography carried out with and without aortic compression.

Renal function was checked in 11 of the 16 cases examined by aortography with aortic compression. In 5 of these the urine was found to be positive for albumin a few days after the examination. In some cases there was also a slight increase in the non-protein nitrogen level but in no case did this exceed 42 mg%. In the case, in which the water test was carried out, failure to concentrate with a fixed specific gravity of the urine was noted, but four weeks after the examination renal function was back to normal. In one case examined by aortography with aortic compression, in which renal function was not checked, the patient was examined by intravenous pyelography on two occasions a few months later. Although fluids had been restricted the shadows of the renal pelves were of poor quality. The possibility cannot be excluded that the disturbance of renal function was related to aortography. The findings in these two cases led us to abandon the use of aortic compression in aortography.

Of the 61 cases examined by aortography without aortic compression, renal function was checked in 9. Albuminuria and an increase in the non-protein level were found only in 1 of these cases. This patient was in the 9th month of pregnancy, and was suspected of having a placenta praevia. In order to obtain both an antero-posterior and a lateral film, pelvic arteriography was carried out on two occasions. As the patient had had repeated severe vaginal bleeding, her blood pressure was so low at the time of the examination that the contrast medium passed very high up into the aorta, and large quantities were thus injected into the kidneys on both occasions. The urine was positive for albumin for ten days after the examination and the non-protein nitrogen level increased to 120 mg%. Two weeks after the examination, however, the non-protein nitrogen level was back to normal. There was no anuria and the output of urine was satisfactory.

Renal function was also checked in another 15 cases examined by pelvic aortography alone. Heller's test was negative, and the non-protein nitrogen level was found to be normal.

Discussion

Aortography succeeds in filling the ovarian artery in a certain number of cases. The ovarian artery may easily be distinguished from the other blood vessels by its position and tortuosity. In the lower lumbar region it is seen to run just lateral to the vertebral transverse processes. It is

generally clearly visible in the angle between the crista iliaca and the fifth lumbar vertebra.

Visualization of the ovarian artery by aortography with aortic compression distal to the origin of the ovarian artery was obtained in a larger percentage of cases than by aortography without aortic compression, *i. e.* 65 and 20 per cent respectively. Two explanations of this observation are possible. The first is that with aortic compression a higher concentration of the contrast medium is probably maintained for quite a long time in the aorta at a point level with the origin of the ovarian artery; this results in better filling of the latter. This improved filling is of great importance in cases in which radiologic demonstration of small blood vessels is the aim. The second explanation probably is that the blood pressure in the uterine artery decreases markedly as a result of compression of the aorta. The contrast medium can therefore pass via the ovarian artery as far as the adnexa and on to the main stem of the uterine artery. A similar technique is used to obtain filling of small blood vessels in cerebral angiography (RUGGIERO et al.).

The marked decrease in the blood pressure in the uterine artery was clearly illustrated by one case in this series (Fig. 1, a and b, record No. 385). Pelvic arteriography resulted in filling of the uterine artery by way of the iliac artery; aortography with aortic compression succeeded in filling the ovarian artery as far as the adnexa. The contrast medium was then seen to flow through the ovarian arcade and on to the uterine artery, filling it in a retrograde direction as far as its point of origin from the internal iliac artery.

Aortography with aortic compression, injecting a 50 per cent solution of Umbradil, involves danger of kidney damage. In this investigation renal function was mainly checked by determination of the non-protein nitrogen level and by Heller's test. These tests are easy to carry out but their reliability in the diagnosis of renal lesions has been questioned. It is therefore interesting to note that in the present investigation the tests revealed albuminuria and an increase in the non-protein nitrogen level only in those cases in which comparatively large quantities of a high concentration of the contrast medium were injected into the renal arteries. Hence, the tests were helpful in demonstrating the risk of renal injury in aortography with aortic compression.

The 12 cases of intra-uterine pregnancy in this series clearly illustrate the difficulty of radiologic demonstration of the ovarian artery during pregnancy. One of these cases was examined by aortography with aortic compression whilst in the other cases compression of the aorta was not applied. Visualization of the ovarian artery was obtained in the first-mentioned case and only in 3 of the other 11 cases. In 3 of these 4 cases the width of the ovarian artery did not exceed 1.5 mm. This width is

Fig. 4. Intra-uterine pregnancy at the 36th week. Low-lying right antero-lateral placenta. u. r., right uterine artery; u. l., left uterine artery. o. r., right ovarian artery; o. l., left ovarian artery, m., markedly enlarged intramural vessels running towards the placental sinuses not yet opacified. The narrow ovarian arteries can hardly contribute to the blood supply of the uterus in this case.

within normal limits, being found also in non-pregnant women with normal adnexa. Fig. 4 shows a radiograph taken in one of these cases. In the fourth case, however; the width of the right ovarian artery was found to be 2 mm whilst that of the left was 3.0 mm. (Fig. 5.)

Fig. 5. A case of premature separation of the placenta in the 9th month, examined by aortography without compression. Both ovarian arteries markedly enlarged.

It thus seems that the ovarian artery occasionally takes part in supplying the pregnant uterus and then increases in width as does the uterine artery. In the cases, therefore, in which radiologic localization of the placenta by pelvic arteriography and opacification of the uterine arteries is tried, and in which only a few or no sinuses show up, visualization of the ovarian artery should also be tried.

The radiologic demonstration of the ovarian artery was of diagnostic value only in 2 cases of our series. In one of these the ovarian arcade was found to be markedly stretched out. This patient had a cyst in the left ovary (Fig. 1 a, b). In the other case, in which there was a tubal pregnancy on the right side, filling of the placental sinuses was obtained by way of the ovarian artery (Diagram 1, record No. 423). In no other case in this series was it possible to diagnose an adnexal tumour from the radiologic appearances of the ovarian artery.

In previous papers it has been shown that visualization of the uterine artery and of its adnexal branches may be obtained by pelvic arteriography (Borell et al. 1952, 1953). The present investigation has

shown that radiologic demonstration of the ovarian artery is likewise possible. All the large blood vessels supplying the internal reproductive organs may thus be studied radiologically. It will doubtless be possible to use aortography with aortic compression for the demonstration of the ovarian artery on a much larger scale as soon as a contrast medium with which there is no risk of renal damage, becomes available. It will then also be possible to obtain a better idea of its importance in the blood supply of the reproductive organs and of the diagnostic value of its radiologic demonstration in cases of adnexal tumour. Admittedly, aortography without aortic compression has hitherto succeeded in rendering the ovarian artery opaque in a small number of cases only. Yet, this method should be given a trial in cases of adnexal tumour in which the uterine artery is not seen to send branches to the tumour.

SUMMARY

Seventy-seven women were examined by aortography. 59 of these were of reproductive age, and 18 at the menopause or post-menopausal. Visualization of the ovarian artery was obtained in 22 of these cases. Aortography with aortic compression resulted in opacification of the ovarian artery in 63 per cent, and without aortic compression in 20 per cent of the cases in this series. As it was found that aortography with aortic compression can interfere with renal function this method was abandoned for the time being.

The radiographic appearance of the ovarian artery is described and the diagnostic value of its demonstration discussed.

ZUSAMMENFASSUNG

Siebenundsiebzig Frauen sind aortographisch untersucht worden. Von diesen waren 59 in fertilem Alter und 18 in der Menopause oder post-menopausal. Die Ovarialarterie war in 22 Fällen darstellbar. Bei Aortographie mit Aortakompression war die A. ovarii in 63 %, ohne Aortakompression in 20 % der Fälle in dieser Serie sichtbar. Da man fand, dass Aortographie mit Kompression der Aorta die Nierenfunktion beeinflussen kann, hat man von dieser Methode jetzt Abstand genommen.

Das Röntgenbild der A. ovarii wird beschrieben und der diagnostische Wert ihrer Darstellung diskutiert.

RÉSUMÉ

Soixante-dix-sept femmes ont été examinées par aortographie, dont 59 en période d'activité génitale et 18 à la ménopause ou ménopausées. L'artère ovarienne a pu être visualisée dans 22 de ces cas. L'aortographie avec compression de l'aorte a donné une opacification de l'artère ovarienne dans 63 % des cas, et sans compression de l'aorte dans 20 % des cas de cette série. Les auteurs s'étant rendu compte que l'aortographie avec compression aortique peut nuire à la fonction rénale ont abandonné pour le moment cette méthode.

Ils décrivent l'aspect radiographique de l'artère ovarienne et discutent l'intérêt diagnostique de sa visualisation.

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TECHNIQUE FOR VISUALISATION OF THE MENTAL FORAMEN

A Case of an Expanding Soft Tissue Tumor in the Mental Foramen

by

G. Mårtensson and *S. Ydén*

It is only extremely rarely that one has reason to visualise the mental foramen radiologically in full detail, which may be the reason why no special projection is described in current radiologic textbooks.

The mental foramen may, however, be confused with a periapical rarefaction. This is pointed out in the literature by WORTH (1951): "Quite often it is represented by a small dark area not very clearly demonstrated. The shadow is occasionally superimposed over the apex of one of the premolars, usually the second one, and may be mistaken for apical infection." The same observation was made by MCCALL and WALD (1952): "Faulty angulation sometimes causes the area to be seen at the apex of one of the bicuspids. In this position it may be mistaken for an indication of a pathologic condition."

Fig. 1. The direction of the mandibular canal at the mental foramen (according to SICHER).

Although one can, as a rule, easily eliminate this source of error by varying the angle of the tube in standard projections of the horizontal portion of the mandible, visualisation of the mental foramen is not clear. This is due to the anatomy of this region. "The canal which opens at the mental foramen is directed outward, upward and backward, and therefore opens at an angle to the outer surface of the mandible;

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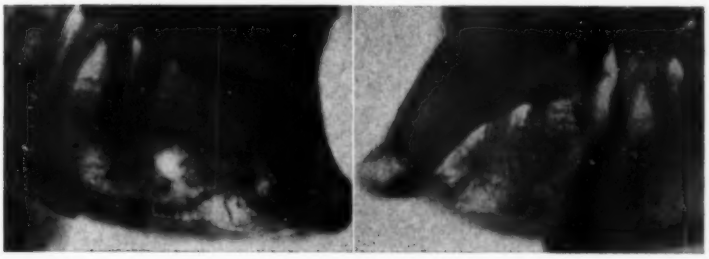


a. b.

Fig. 2. Standard films of the right (a) and left (b) mandible. The right mental foramen is appreciably wider than the left.

consequently, the rima of the foramen is sharp only at the anterio inferior circumference" (SICHER 1949) (Fig. 1).

A special projection should, therefore, be used to demonstrate pathologic changes in and around the mental foramen. This is illustrated by the following case which, being rather rare, we feel may be of interest to report.

Case report No. Md. s. 713. Male, aged 23 years. The patient had suffered periodically from a dull aching pain in the anterior part of the right side of the mandible for at least a year. Clinical examination revealed a very slight swelling at the level of the apices of the premolars on that side. The ordinary standard film of the right side of the mandible showed a radiolucent area, the size of a pea, which suggested a widening of the mental foramen, particularly when compared with the opposite side (Figs. 2 a and b).

By using the following special projection, information of value in the differential diagnosis was obtained. With the film fixed between the teeth of the upper and lower jaws as laterally as possible, the tube is centred as for an axial projection of the mandible and tilted 30—40 degrees towards the affected side so that the central ray is directed as far as possible at right angles to the transverse

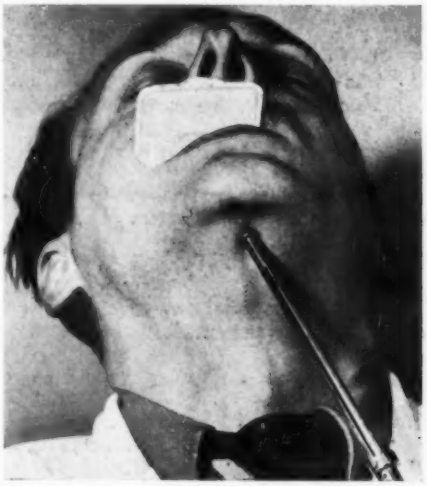
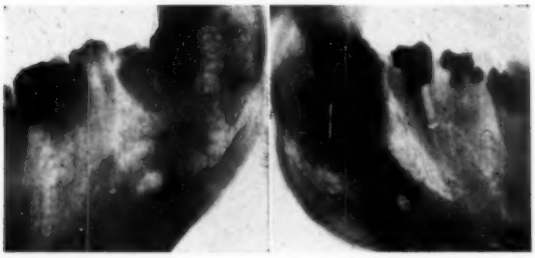


Fig. 3. Position for special projection of the mental foramen.



a. b.

Fig. 4. a. Appreciably widened right mental foramen with pea-sized area of destruction. b. Normal left foramen.

plane through the opening of the mandibular canal (Fig. 3). As can be seen in Figs. 4 a and b, the visualisation of the mental foramen is better defined than in the standard projection (cf. Figs. 2 a and b). The right mental foramen is seen to be appreciably wider than the left. Furthermore, there is a round clearly demarcated area of destruction, the size of a pea, at its upper margin, though no reaction was present in the surrounding bone.

The tentative diagnosis of a soft tissue tumour associated with the inferior alveolar nerve was verified at the subsequent operation. At the operation a thickening of the inferior alveolar nerve, clearly demarcated from surrounding tissue, was found at its exit from the mental foramen. This thickened portion of the nerve extended two or three millimeters into the canal. The superficial layer of the nerve was resected. Histologic examination revealed dense, fibrous tissue of a neurofibromatous character.

SUMMARY

The authors describe a special projection of the mental foramen used in a case of expanding soft tissue tumour in this region.

ZUSAMMENFASSUNG

Die Verfasser beschreiben eine Spezialprojektion des Foramen mentale, welche in einem Fall mit ausgedehntem Weichteiltumor in dieser Region benutzt wurde.

RÉSUMÉ

Les auteurs décrivent une incidence spéciale pour le trou mentonnier, employée dans un cas de tumeur des parties molles de cette région.

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FROM THE ROENTGEN DEPARTMENT (DIRECTOR: PROFESSOR P. FLEMMING MØLLER), RIGSHOSPITALET, COPENHAGEN, DENMARK

INFLAMMATORY CHANGES IN THE BRONCHIAL GLANDS IN CHRONIC BRONCHITIS, DEMONSTRATED BRONCHOGRAPHICALLY

by

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The introduction of bronchography by SICARD and FORESTIERS in 1922 opened new and wider opportunities for the study of bronchial diseases in vivo.

In many patients with chronic bronchitic symptoms bronchography also proved especially valuable in revealing bronchostenosis or bronchiectasis. Specific roentgenologic bronchitic changes are not observed, however, and a normal bronchogram does not preclude the possibility of chronic bronchitis.

It is sometimes also possible to demonstrate roentgenologically some of the patho-anatomic changes in chronic bronchitis. One such change is the filling of dilated glands and the efferent ducts of the glands in the walls of the bronchi with contrast medium. The changes resemble those observed in inflammatory conditions in the urethra, where filling of the para-urethral ducts is frequently visualized at urethrography.

The patho-anatomic picture in chronic bronchitis is well known. Macroscopically the mucosa is red, swollen and covered by a mucous or purulent exudate.

Microscopically there is leucocytic infiltration, and an accumulation of mucus may be observed in the submucosal glands. The efferent ducts of the glands are comparatively long and dilated, providing conditions favourable to infection of deeper penetration and further weakening and destruction of the wall as the result. There is scarcely any doubt that such dilated efferent ducts represent pronounced bronchitic changes. A roentgenologic demonstration of this condition was first described by STUTZ (1948, cited by STILLER), who observed a peculiar sac-like pro-

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trusion of the bronchial wall at the site of the inferior medial limit of the main bronchi in the bronchograms from three patients.

STILLER (1949) reported two similar cases, and FISCHER (1950) reported five, of which four had extensive bronchiectasis. The fifth patient had a large, stenosing bronchial tumour with resultant pronounced bronchitic changes demonstrated at autopsy.

In agreement with STUTZ and STILLER, FISCHER maintained that the changes are observed especially at the site of the most inferior limitation of the bronchial wall, although he also obtained glandular duct filling all the way out to the third bronchial bifurcations.

FISCHER stated that the reason why he observed these changes bronchographically lay in his use of a water-soluble contrast medium, Joduron B. The lower surface tension of this solution, in his opinion, facilitates its penetration into the efferent ducts of the glands. FISCHER contended, on the other hand, that the oil-base contrast media are not suitable for this purpose.

That filling of the efferent ducts of the glands is also possible with an oil-base contrast medium in the main bronchi as well as peripherally is demonstrated, however, by the following eight cases. Thus, it is not so much the composition of the contrast medium to which the failure to observe the filling of the glandular ducts may be ascribed, but rather to the fact that heretofore insufficient attention has been paid to the changes and their significance.

Case Reports

Case 1. (6584/49.) 46-year-old labourer with a history of cough since childhood. Expectoration of tenacious whitish sputum during the previous 25 years, and functional dyspnea of 30 years' duration, which incapacitated him for work at the time of the investigation. Increasing fatigue and loss of weight in the latter years.

Clinical examination: Clubbing of the fingers and cupped finger and toe nails. Otherwise nothing pathologic. *Roentgen examination of the lungs:* Somewhat enlarged hili, but otherwise normal conditions.

Bronchography (bilateral): Adequate filling obtained but no evidence of bronchiectasis or stenosis. In the branches to both the upper and lower lobes abundant projections from the bronchial wall were visualized indicating filling of the bronchial glands (Fig. 1).

Case 2. (4378/49.) 48-year-old industrial worker. Six years before admission bilateral pneumonia on four occasions. Six months before admission cough with expectoration and functional dyspnea developed; on roentgen examination an enlarged and dense shadow was observed in the right hilar region. The patient was therefore placed under observation for a suspected right pulmonary tumour.

Clinical examination: Nothing pathologic worthy of note. Study of the pulmonary function showed 2.1 liters (41 per cent) vital capacity and 3.05 liters residual air (59 per cent of the total capacity). *Bronchoscopy:* Redness of the mucosa and mucous secretion in both main bronchi. No signs of tumour were observed. *Microscopic examination of the*

Fig. 1. Case 1. Abundant pendulous projections from the bronchial wall, representing filling of the glandular ducts with contrast medium.

Fig. 2. Case 3. Filling of the glandular ducts with contrast medium in both larger and smaller branches of the bronchi.

bronchial secretion: Clumps of macrophages and leucocytes as well as fibrin, epithelial cells and some bacteria, but no tumour cells. *Roentgen examination of the lungs* showed a slightly enlarged right hilar region, but no other changes.

Bronchography (right side). Adequate filling of the bronchial tree. No signs of bronchiectasis or stenosis were observed, but the bronchus to the middle lobe was slightly narrowed; the contours were irregular with small projections as manifestations of the penetration of the contrast medium into the efferent ducts of the glands. There was a similar filling of the glandular ducts at the site of the branch to the lower lobe.

C a s e 3. (20972/53.) 50-year-old labourer with a history of functional dyspnea and recurrent bronchitis of many years' duration. The symptoms had increased greatly in severity during the previous two years, leading to total incapacity for work at the time of the investigation. He had a severe cough with expectoration of tenacious sputum; in the mornings the sputum was frothy. The morning temperature was subfebrile.

Clinical examination: Chest: Increased resonance on percussion. Expiration prolonged, diffuse sibilant rhonchi. *Roentgen examination of the lungs* revealed pronounced emphysema and somewhat increased density of the hili but otherwise no changes.

Bronchography (right side): Adequate filling of the bronchial tree. No signs of bronchiectasis or stenosis were observed. In the main branches to the upper and lower lobes as

Fig. 3. Case 4. Lateral projection. Glandular duct filled with contrast medium in the first part of the lingular branch.

Fig. 4. Case 5. Glandular duct in the bronchus to the upper lobe, filled with contrast medium.

well as farther out in the peripheral branches abundant small pendulous projections from the wall were visualized as manifestations of the filling of the efferent ducts of the bronchial glands (Fig. 2).

Case 4. (671/54.) 37-year-old farm worker with a history of bronchial asthma of many years' duration. During the previous nine years he had received an invalid's pension because of his condition. No history of pneumonia. The patient's health had deteriorated greatly the previous few months, with attacks of dyspnea and coughing with abundant expectoration.

Clinical examination: The lungs were observed to be distended. Respiration vesicular with prolonged expiration. Abundant rhonchi over both lung fields. *Bronchoscopy:* Considerable mucosal swelling about the site of origin of the branches to the upper lobes on both sides. Abundant thin secretion in these branches; the branches to the lower lobes normal in appearance. *Roentgen examination of the lungs* showed emphysema, but otherwise no obvious changes.

Bronchography (left side): Adequate filling of the bronchial tree. No signs of bronchiectasis or bronchostenosis observed. In the first part of the lingular branch, filling of the bronchial glandular ducts was seen (Fig. 3).

Case 5. (262/54). 76-year-old sheet metal worker with a 15 year history of bronchitis with frequent cough and abundant expectoration. Six years and two years previously, respectively, he had been admitted to hospital with pneumonia.

Fig. 5. Case 6. Lateral projection showing filling of glandular ducts with contrast medium, corresponding to the right middle and lower lobe branches.

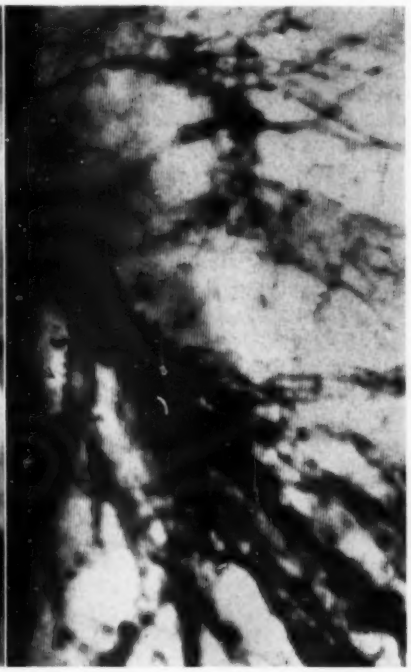

Fig. 6. Case 7. Abundant glandular ducts, both centrally and peripherally filled with contrast medium.

Clinical examination showed the patient to be adequately nourished. He was dyspneic; pulmonary distension, covering the heart noted. No abnormal respiratory sounds. *Roentgen examination of the lungs:* Rather pronounced emphysema, but otherwise no obvious changes.

Bronchography (*right side*): Good filling of the bronchial tree. Corresponding to the bronchus to the upper lobe many pendulous and sac-like projections from the wall were visualized, representing the filling of efferent ducts of the bronchial glands (Fig. 4).

Case 6. (2028/54.) 55-year-old bricklayer. At the age of 21 pneumonia and since the age of 30 persistent bronchitis every winter. During latter years he had a severe cough with expectoration as well as pronounced dyspnea when working.

Clinical examination: The patient was somewhat undernourished. No cyanosis or dyspnea at rest. Pulmonary stethoscopy revealed pulmonary distension in the cardiac region. Abundant sonorous rhonchi. *Bronchoscopy:* The mucosa in the lowest part of the trachea was red and swollen. The changes increased basally in both main bronchi. Abundant tenacious mucus. No signs of tumour. *Roentgen examination of the lungs* showed

slight emphysema and comparatively marked fibrosis. The lung structure appeared partially as a coarse network. No infiltration of the parenchyma, no atelectasis.

Bronchography (*right side*): The bronchial tree was adequately filled. No signs of bronchiectasis or bronchostenosis. The branches to the lower and middle lobes had somewhat irregular contours with abundant pendulous projections from the walls indicating penetration of the contrast medium into the efferent ducts of the bronchial glands (Fig. 5).

Case 7. (2014/54.) 28-year-old farm worker. On four occasions during childhood and youth pneumonia. There was a long history of cough with much expectoration as well as pronounced functional dyspnea, from which, during the previous three years he had been incapacitated for work.

Clinical examination: No cyanosis or dyspnea at rest. Diffuse rhonchi on auscultation but otherwise no abnormality detected. *Bronchoscopy:* Tenacious secretion in both main bronchi. Slight dilatation at the site of the origin of the bronchus to the lower lobe and atrophic mucosa at that site. No signs of tumour. *Roentgen examination of the lungs* showed a distended and coarse network-like appearance at both bases. No infiltration or exudate was visualized.

Bronchography: Adequate filling of the bronchial tree. The inferior peripheral branches on both sides were very fine, resembling the changes in bronchial asthma. Isolated, sacular bronchiectatic cavities were observed corresponding to the most anterior lateral branch of the lower lobe on the right side, as well as isolated cystic dilatations corresponding to the most anterior lower lobe branch on the left side. In the main bronchi as well as in the peripheral branches abundant pendulous projections from the bronchial wall — the filled efferent ducts of the glands — were observed (Fig. 6).

Case 8. (292/54.) 51-year-old labourer with a history during latter years of marked functional dyspnea and severe cough with expectoration of abundant foamy sputum. He had had frequent febrile periods.

Clinical examination showed slight cyanosis, but no dyspnea at rest. No other abnormality noted. *Bronchoscopy* was not performed. *Roentgen examination of the lungs* showed a rather pronounced network-like appearance posteriorly at the right base. No changes on the left side.

Bronchography revealed cylindric ectasia corresponding to the branch to the lower lobe. Filling of the efferent ducts of the glands in the main bronchi was observed.

Conclusion

These eight cases, like the examples in the literature mentioned earlier, demonstrate that concurrently with the filling of the efferent ducts of the bronchial glands with contrast medium there are pronounced inflammatory changes in the walls. In contrast to the results of other writers, we observed that the filling of the efferent ducts situated superiorly was almost as pronounced as that of those corresponding to the most inferior limitation of the wall. This may be explained by the fact that the patients were examined in the erect as well as the recumbent position.

The changes must be accepted as indicating the presence in the mucosa of rather pronounced inflammatory changes. It is impossible to determine

from the filling of the glands alone whether these are primary or secondary to other conditions.

These observations are interesting and not uncommon, but are not manifestations of specific changes in the bronchial wall, other than those due to chronic bronchitis.

Addendum

Since the preparation of this manuscript, one of us (GUDBJERG), in going through 112 cases of verified bronchiectasis, has found a further six cases of contrast filling of the ducts of the bronchial glands. Furthermore, up to the end of the month of May 1954, he has encountered a further 7 cases, all with manifestations of bronchitis, and in two of these additional bronchiectasis.

SUMMARY

Eight cases of chronic bronchitis are reported in which the efferent ducts of the bronchial glands were filled with contrast medium on bronchography with iodized oil. This observation is considered analogous to the filling of para-urethral ducts with contrast medium in urethritis. The changes are considered indications of comparatively severe inflammatory lesions of the bronchial mucosa.

ZUSAMMENFASSUNG

Acht Fälle mit chronischer Bronchitis werden berichtet, bei denen die efferenten Gänge der Bronchialdrüsen bei der Bronchographie mit Jodöl mit dem Kontrastmittel gefüllt wurden. Diese Beobachtung wird der Kontrastfüllung der paraurethralen Gänge bei der Urethritis gleichgestellt. Es wird angenommen, dass die Veränderungen verhältnismässig schwere entzündliche Schädigungen der Bronchialschleimhaut anzeigen.

RÉSUMÉ

Les auteurs rapportent huit cas de bronchite chronique où les conduits efférents des glandes bronchiques se sont remplis de produit de contraste au cours de bronchographie avec l'huile iodée. Ceci leur paraît analogue au remplissage des canaux paraurétraux par le produit de contraste dans l'urétrite. Ils considèrent cette modification comme le signe de lésions inflammatoires assez graves de la muqueuse bronchique.

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SPINAL CORD DAMAGE IN ABDOMINAL AORTOGRAPHY

by

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In working out a method for pelvic arteriography in dogs, we observed a complication which, excepting in one doubtful case, we have not been able to find reported in man.

A ten-year-old dog was anesthetized with mebumal and subjected to arteriography, a 70 per cent diodrast solution (Nycotrast) being injected in a proximal direction into the femoral artery. Three successive injections were given. The interval between the first two injections was about 5 minutes, while the last injection was given half an hour later. The dosage was 10 + 10 + 20 ml. During the last injection and immediately following it, the animal developed clonic spasms in the hind parts and as the effect of the anesthesia wore off, was found to be paralysed and possess no sensation in its hind legs.

The roentgenograms showed that the contrast medium filled the entire abdominal aorta and its dorsal branches, whereas the ventral branches were but poorly outlined (Fig. 1).

Autopsy revealed no macroscopic or microscopic signs of damage to the spinal cord. In spite of this we were inclined to consider the lesion as a toxic one caused by the contrast medium.

Clinical experience has shown that cerebral angiography carried out by means of contrast media of the diodrast type, especially when high concentrations are used, may cause signs of a cerebral lesion. BROMAN and OLLE OLSSON (1948, 1949) showed experimentally that concentrated media of the diodrast type gave rise to toxic damage to the brain in rabbits and that the nature of the lesion was due to disturbances of the permeability of the cerebral vessels. This kind of toxic damage produces no microscopic lesions apart from some hyperemia.

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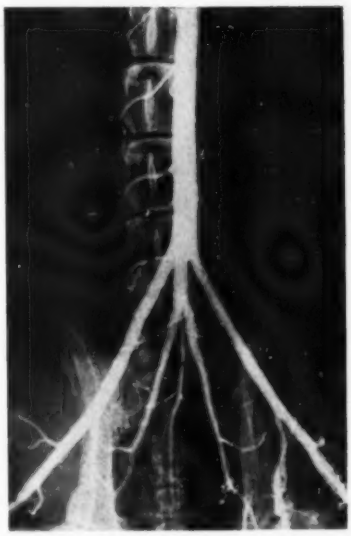


Fig. 1. Abdominal aortography (dog) in supine position performed via the femoral artery. Nycotrast 70 %. The aorta and the dorsal branches of the aorta are completely filled with contrast medium, while the ventral branches are but poorly outlined.

In cerebral angiography one intentionally fills the actual circulatory system with contrast medium for a short time. The importance of avoiding the use of highly concentrated contrast medium is evident. In abdominal aortography the great stream of blood will rapidly dilute the contrast medium and thus reduce the possible risks of the procedure to a minimum.

Damage to the spinal cord may be expected theoretically under the following circumstances, alone or combined.

1. *Supine position of the subject.*

Due to its high specific gravity the contrast medium predominantly fills the dorsal arteries so that it is highly concentrated in the arteries supplying the spinal cord. Aortography performed with a catheter in the femoral artery favours a filling of this type in which the dorsal branches of the aorta, including the renal arteries, will be well outlined (Fig. 1).

On the other hand, in translumbar aortography the patient lies prone, favouring an abundant and often disturbing filling of the mesenteric (ventral) vessels.

2. *Prolonged exposure to the contrast medium*, as resulting from retardation of the blood stream in the aorta, *e. g.*, aortic coarctation, embolus or thrombus formation, reduced blood pressure, abdominal compression and possibly injections too violently performed in a proximal direction.

3. *Repeated injections at short intervals.*

4. *Pre-existing weakening of the spinal cord arteries.*

The last 3 items were demonstrated in the brain of rabbits by BROMAN, FORSSMAN and OLLE OLSSON (1950).

The following study was carried out in an effort to elucidate whether or not abdominal aortography under unfavourable conditions may give rise to damage of the spinal cord in experimental animals.

Experimental

The experiments were carried out on rabbits weighing from 2 to 3 kg, anesthetized with ether. In one group the contrast medium was injected with the animals supine while in a control group the prone position was used. After injection of the contrast medium a saturated solution of trypan blue in saline was introduced intravenously, and the animals were kept alive for a few minutes before they were bled. The dye solution was then washed from the vessels by means of saline and the animals were fixed in 10 per cent formalin.

This technique for demonstrating disturbances of the permeability of the vessels was introduced by BROMAN (1940) and has been used by BROMAN and OLLE OLSSON (1948, 1949) and BROMAN, FORSSMAN and OLLE OLSSON (1950). These authors have shown that if trypan blue is injected into an experimental animal in which a localized disturbance in the permeability of the blood vessels of the brain has been produced by means of contrast medium, the dye will find its way into the injured region of the brain, which will be coloured while the remainder of the organ will remain unstained.

Dorsal puncture of the aorta in rabbits is rather difficult. A frontal puncture on the other hand necessitates extensive opening of the abdomen and involves certain risks of bleeding. We found a useful method was to inject the contrast medium into the left renal artery employing this artery as a prolonged cannula into the aorta. The left kidney was exposed through a small lateral abdominal incision and its vessels were ligated. Proximally to the ligature a blunt cannula was inserted into the artery in a proximal direction and ligated to it. In this manner the position of the animal could be altered with the conditions of injection remaining unchanged (Fig. 2). The dye solution was injected into one of the femoral veins or the brachial vein of the left foreleg over a period of about 10 minutes. The spinal cord was removed and examined macroscopically for possible staining of the nervous tissue.

The reactions of the animal after the injections were noted. In many of the animals a slight transient respiratory depression developed following the injection of the contrast medium, and some of them died owing to respiratory paralysis. These animals, together with some others which

Fig. 2. Experimental arrangement. Rabbit in supine position, with left kidney exposed through an incision in the abdominal wall. Cannula ligated to renal artery.

died as a result of technical mishaps, are excluded from the material. A 70 per cent diodrast solution (Nycotrast) was employed in all these experiments.

Results

The results are shown in the table.

One single injection of the contrast medium (injection time 10 sec.) in an animal in the supine position gave a slight bluish colouring of the spinal cord (No. 1). Reducing the speed of injection (injection time 120 sec.) we also observed slight staining but now more caudally in the lumbar enlargement (No. 2).

When the injection of the contrast medium was repeated after an interval of two minutes, the rabbits in many instances showed widespread lesions in the spinal cord from the level of the injection site caudally to the medullary cone (Nos. 3 to 10). The duration of each injection varied from 15 to 60 sec. In many of the animals spasms developed in the hind parts, and some animals temporarily recovering from the narcosis, were paralysed in the hind extremities.

In the control group with the animals in the prone position we could inject at a slow speed up to 10 ml of the contrast medium, divided in 3 portions injected at intervals of 2 minutes, without being able to detect any staining of the spinal cord (Nos. 11 to 17).

In one rabbit in this group the injection was repeated thrice at intervals of 2 minutes. The total contrast medium dose was 13.5 ml and the total injection time 20 sec. Definite damage of the spinal cord was observed. The rapid injection of this large dose might have resulted in incomplete mixing with the aortic blood so as to give a high concentration of the contrast medium in the dorsal vessels as well, in spite of the prone position of the animal. This animal is not included in the table.

Table 1

	Experiment No.	Inj. vol. (Interval: 2 min.)	Total inj. time	Permeab. lesion at the:		Spasms
				inj. site	lumb. enlargement	
Supine position	1	5.0 ml	10 sec.	(+)	—	(+)
	2	5.0 »	120 »	—	(+)	—
	3	2.0 + 1.2 »	35 »	+	+	+
	4	2.5 + 2.5 »	60 »	(+)	+	+
	5	1.5 + 2.0 »	60 »	+	+	++
	6	3.5 + 1.5 »	65 »	+	+	++
	7	2.5 + 2.5 »	80 »	+	—	(+)
	8	2.5 + 2.5 »	120 »	(+)	—	+
	9	2.5 + 2.5 »	120 »	+	+	—
	10	2.5 + 2.5 »	120 »	+	—	—
Prone position	11	1.5 + 2.0 »	60 »	—	—	—
	12	2.0 + 3.5 + 2.5 »	180 »	—	—	—
	13	2.0 + 2.0 + 2.0 »	180 »	—	—	—
	14	2.0 + 2.0 + 2.0 »	180 »	—	—	—
	15	3.0 + 3.0 + 3.0 »	215 »	—	—	—
	16	3.0 + 3.0 + 4.0 »	205 »	—	—	—
	17	2.0 + 2.0 + 3.0 »	220 »	—	—	—

Discussion

It is obvious that contrast media of the diodrast type if used in rabbits in a 70 per cent concentration under unfavourable conditions are liable to interfere with the permeability of the spinal cord vessels. Due to the high specific gravity of the contrast medium, such injury is easier provoked when the animal is lying supine, the spinal arteries obtaining almost undiluted contrast medium. This is clearly shown in Fig. 3.

The Danish anatomist NIELS STEENSEN (1638—1686) compressed the abdominal aorta in rabbits at the level of the renal arteries and thus produced paralysis in the hind part of the animal (STENO's *experiment*). In order to exclude damage to the spinal cord due to aortic compression in one group, the animals in our two groups were all treated alike. The animals injected with the contrast medium in the prone position were kept in that position only during the actual injection of contrast medium.

It may be assumed that these observations on rabbits also hold good for other animals. The lesion in question, however, must be expected to arise more readily in rabbits than in carnivorous animals (dogs) and in man, because of the ontogenetic ascent on the spinal cord which takes place in the latter beings. In the rabbit the medullary cone terminates in the sacral region, in the dog between the 6th and 7th lumbar vertebra

while in man the spinal cord terminates at the level of the first lumbar vertebra (Fig. 4).

Reverting to the dog mentioned, we wish to emphasize that it was lying supine; the direction of the blood stream was the opposite to that

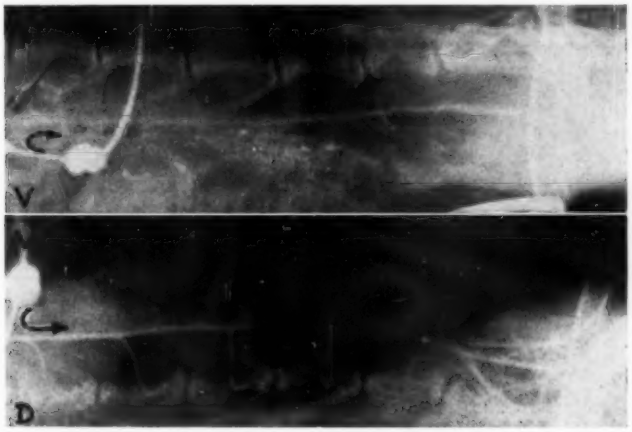


Fig. 3. Abdominal aortography in rabbit. Contrast medium (Nycotrast 70 %) injected via left renal artery.
Above: Prone position
Below: Supine position
Note the different distribution of the contrast medium.

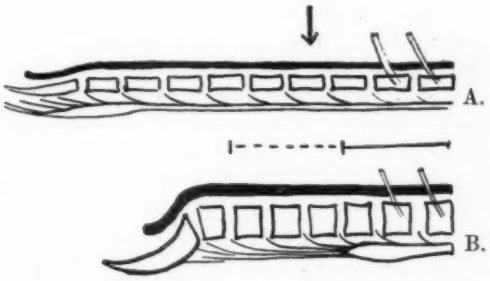
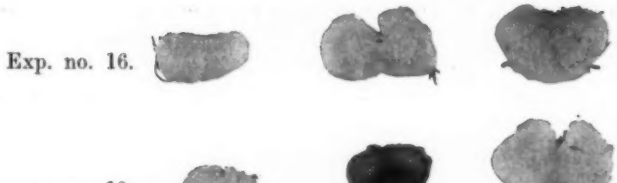


Fig. 4. Relation between aorta and the spinal cord in rabbit (A) and in man (B). The arrow indicates the site of injection in rabbit. The solid line shows the most actual area in man, the dotted line a possible low-arising arteria radicularis magna.

of the injection which was repeated twice, and the animal was ten years old. Under such unfavourable conditions the spasms, and the paralysis of the hind parts which appeared when the dog recovered consciousness, was most likely a result of toxic damage to the spinal cord by the contrast medium.



Sections through the spinal cord of rabbit. Passage of trypan blue into the nervous tissue after aortography with diodrast 70 % under unfavourable conditions. Exp. no. 3 and 10 injected in supine position, no. 16 in prone position. Sections through the: A thoracic, B upper lumbar (injection site) and C lower lumbar region.

Concerning aortography in dogs we have found only one report of importance. HENLINE and MOORE (1936) performed aortography in 19 dogs. After translumbar puncture of the aorta they turned the animal into the supine position and compressed the lower part of the abdomen. Some of the animals exhibited clonic spasms in the hind legs during the injection in spite of being in deep narcosis. The authors were inclined to explain the spasms as a result of a toxic action on the muscles and nerve endings. They used toxic contrast media and the compression of the abdomen in the supine position favoured entrance of, and prolonged exposure to, the contrast medium in the spinal cord arteries. The clonic spasms observed confirm the assumption that such toxic lesions may occur in the dog.

We presume that toxic spinal cord damage due to contrast media may even occur in man under unfavourable conditions. The arteries supplying the spinal cord are derived from the rami medullae spinalis from the segmental aortic and deep cervical branches. In the lumbar region one (or two) vessels, the arteria radicularis magna, arise between the eighth thoracic and fourth lumbar segments. In the thoracic region there is one artery in the lower, none or one in the middle and one or two in the upper region. Furthermore, there are one or two in the lower and one in the upper cervical region (SUH and ALEXANDER, 1939). Because of this arrangement of the blood supply to the human spinal cord, the lesions in rabbits due to contrast media must be situated at the level

of the injection site to be comparable with similar damage in man (Fig. 4); lesions at this level were observed in our experiments (see table).

ANTONI and LINDGREN (1949) reported a case of translumbar aortography in man with fatal results. The patient was in narcosis in the prone position with a pillow under the abdomen. Parts of the contrast medium were injected extravasally, but some of it filled the upper part of the abdominal aorta and the superior mesenterial vessels. From the level of the upper part of the second lumbar vertebra downwards, the aorta was compressed and not patent. When the effects of the narcosis had worn off, the patient was found to be paralysed in the lower extremities, bladder and rectum. He died two months later.

The authors concluded that the paralysis was caused by spinal cord anoxemia due to the aortic compression (STENO's *experiment*). However, this complication has never been observed previously in man despite the use of aortic compression in numerous instances in obstetric practice. The lesion may well be considered a chemico-toxic one. Due to the aortic compression, the contrast medium in spite of its high specific gravity may have been forced into the dorsal arteries. Above the compression the circulation was probably slow, causing a retention of, and prolonged exposure to, the concentrated contrast medium.

Conclusions

Repeated injections of a 70 per cent solution of contrast medium of the diodrast type into the abdominal aorta in rabbits may give rise to toxic damage to the spinal cord demonstrable as permeability lesions of its vessels. Spasms and paralysis were also encountered. The lesions occurred in animals injected in the supine position.

In animals injected in the prone position we never observed spasms or paralysis. In this group we found no lesions except in one case in which excessive doses were employed with rapid injection of the contrast medium.

Experiments are in progress to determine whether similar lesions may be produced under other unfavourable conditions.

Acknowledgement

The experiments have been carried out under a grant from *Norwegian Research Council for Science and the Humanities*. We are indebted to Prosector STIAN ERICHSEN for kind permission to work at the *Laboratory of Pathology of the Norwegian Veterinary College*, and to Professor H. F. WIRSTAD for allowing us to perform the roentgenologic part of the experiments at the *Surgical Clinic of the Norwegian Veterinary College*.

SUMMARY

In an attempt to elucidate whether abdominal aortography may cause damage to the spinal cord, abdominal aortography was carried out in 18 rabbits, with injection

of the contrast medium (Nycotrast 70 %) via the left renal artery. The position of the animal was found to be important, 3.2 to 5 ml in 10 rabbits in the supine position giving rise to disturbance of the permeability of the spinal cord vessels; spasms and paralysis also occurred. Larger doses in 7 rabbits in the prone position produced no visible lesion. The significance of these findings and their possible importance in aortographic examinations in man is discussed.

ZUSAMMENFASSUNG

Zur Beleuchtung der Frage, ob die abdominale Aortographie eine Schädigung des Rückenmarks hervorrufen könne, wurde bei 18 Kaninchen eine derartige Aortographie durch Injektion des Kontrastmittels (Nycotrast 70 %) in die linke Nierenarterie ausgeführt. Man fand, dass die Lage der Tiere von Bedeutung ist, denn in Rückenlage ergaben 3.2 bis 5 ml bei 10 Kaninchen Permeabilitätsstörungen der Rückenmarksgefässe; auch Spasmen und Lähmungen traten auf. In Bauchlage erzeugten grössere Dosen bei 7 Kaninchen keine sichtbare Schädigung. Die Bedeutung dieser Befunde und deren möglicher Wert für die aortographischen Untersuchungen des Menschen werden besprochen.

RÉSUMÉ

Pour essayer de déterminer si l'aortographie abdominale peut être nocive pour la moelle épinière, les auteurs ont pratiqué une aortographie abdominale sur 18 lapins, en injectant le produit de contraste (Nycotrast 70 %) par l'artère rénale gauche. La position de l'animal s'est avérée importante, 3.2 à 5 cc. donnat lieu chez 10 lapins en décubitus dorsal à une perturbation de la perméabilité des vaisseaux de la moelle épinière; des spasmes et des paralysies se sont aussi produits. Des doses plus fortes administrées à 7 lapins en procubitus n'ont pas donné de lésion visible. Les auteurs examinent la signification et l'importance éventuelle de ces résultats pour l'examen aortographique chez l'homme.

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FROM THE ROENTGEN DEPARTMENT (DIRECTOR: J. FRIMANN-DAHL), ULLEVÅL HOSPITAL, OSLO, NORWAY

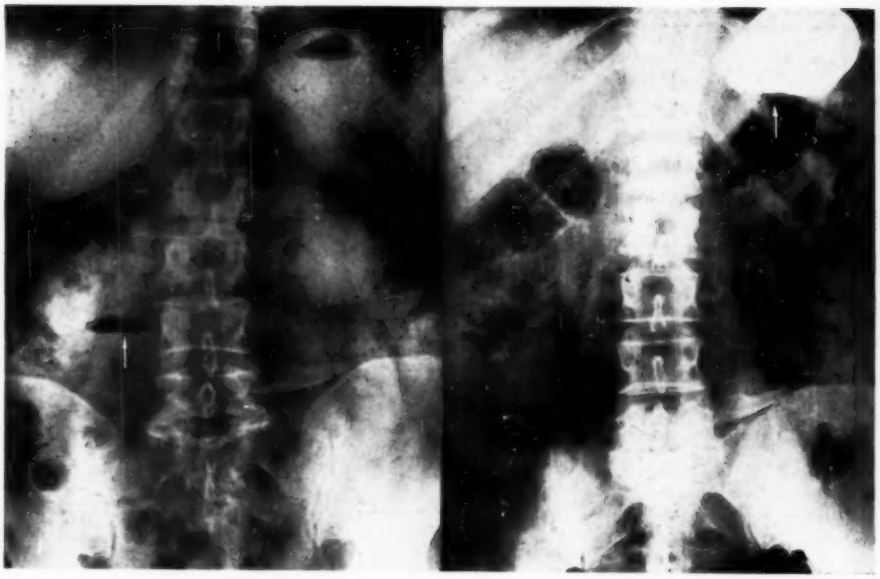
THE ADMINISTRATION OF BARIUM ORALLY IN ACUTE OBSTRUCTION; ADVANTAGES AND RISKS

by

J. Frimann-Dahl

Barium sulphate suspended in water, combined with some substance to prevent flocculation, is the contrast medium of choice for examinations of the intestinal tract. It is not absorbed and has no toxic effect. Its employment is accepted without reservation in ordinary cases, but its value does not seem to be generally appreciated in acute abdominal conditions. The question has been much discussed in the literature and it is still maintained even in modern textbooks that the administration of barium by mouth is dangerous and even contraindicated in acute obstruction. (The Textbook of CHRISTOPHER, STICK, SCHINZ, BAENSCH & FRIEDL, as well as that of SHANKS, KERLEY et al.) This view is in some way valid for the large bowel, but is not correct as far as acute small bowel obstruction is concerned. Whence is this out-of-date notion derived? It goes back to the early twenties when there was still little experience in roentgen examination of acute abdominal conditions. It may then have happened that barium sulphate was given orally in stenosis of the large bowel. The barium suspension has a tendency to become inspissated when water is resorbed from the colon and an incomplete obstruction may thus have been rendered complete. Such an accident has fortunately not occurred in our department. In small bowel obstruction the contrast medium becomes more and more diluted, the nearer it reaches the site of the stenosis. Consequently, precisely the opposite of that generally believed, occurs. In the small bowel it seems impossible for the barium to become thickened and dangerously increase the degree of obstruction.

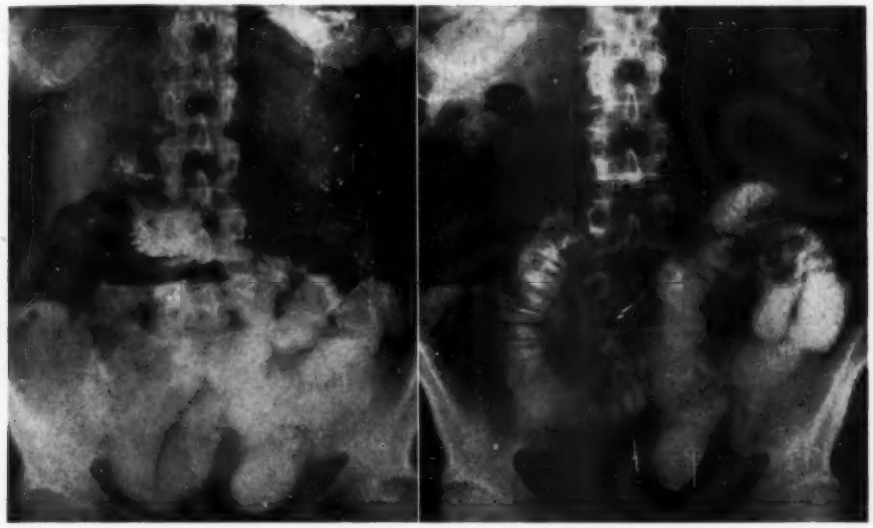
Paper read at the Seventh International Congress of Radiology, Copenhagen 1953; submitted for publication, Oct. 23, 1953.



a. b.

c.

Fig. 1. a. Mechanical obstruction of ten hours' duration. Small fluid levels in terminal ileum. b. Two hours later, and following a barium meal, the contrast medium lies in the fornix of the stomach. c. After a further three hours, the barium is arrested at site of stenosis. Operation revealed a marked band-like adhesion.



a. b.

Fig. 2. a. Simple obstruction, five hours. b. At sixteen hours minimal amount of barium has passed the stenosis. Operation revealed occlusion due to band.

It is all important to decide from the routine films whether the obstruction is situated in the small or large intestine. If a large bowel obstruction is most likely, the approach to a definite diagnosis is the barium enema. However, in some instances it is impossible to decide in which part of the tract the stenosis is situated. This happens when the small intestine is markedly distended and the mucosal pattern nearly obliterated. A barium enema should then also be given and an examination of the large bowel carried out. Should the lumen be clear, the obstruction must obviously lie in the small intestine.

We try always to arrive at a satisfactory diagnosis without employing any contrast medium, but as soon as doubt arises, barium is given by mouth and its passage followed. (Fig. 1, a, b, c.) This method was advocated by Scandinavian authors twenty to thirty years ago (LAURELL, KOCH, HØYER, FRIMANN-DAHL). CASE (1930), proposed the use of thorium in all cases of small bowel obstruction. However, no contrast medium has, as yet, replaced the barium sulphate mixture. Not more than half a tumblerful (50 cc) of the suspension (two parts barium sulphate to three parts water) should be swallowed by the patient. The amount of the intake must be carefully observed. If too large,

a. b.

Fig. 3. a. Strangulation with obstruction (barium by mouth, ten hours). b. At fourteen hours findings similar to those of a simple occlusion. Operation revealed 30 cm of ileum incarcerated under band.

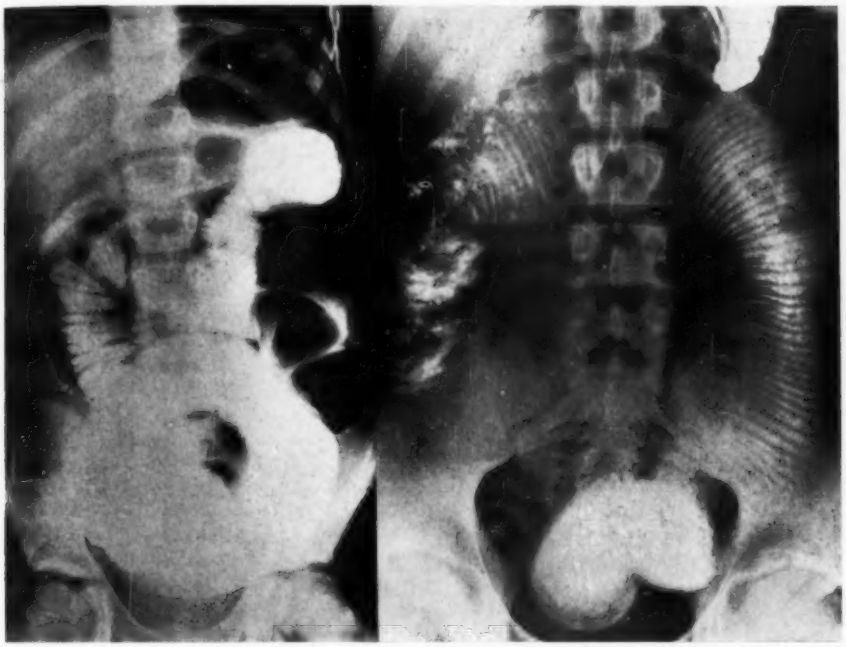
it may mask the entire abdominal field and also reduce the diagnostic possibilities. In such cases, criticism of the procedure may be justified.

The patient must be turned on his right side so as to promote the flow of the suspension through the pylorus and prevent it collecting and remaining in the fornix for days as may occur if the patient lies on his back the whole time (Fig. 1, b). This is an important point which must be carefully watched in the wards. As a rule the contrast medium passes into the jejunum in the course of one hour, the further passage depends on the site and degree of the obstruction.

Advantages

Why is this method to be recommended in small bowel obstruction? The following features speak in favour of this procedure:

1. The patient with uncertain signs of ileus is kept under control and any amelioration or deterioration is comparatively easily detected. There are only two possibilities, either the contrast medium must pass over into the colon, or be arrested by the obstruction. In the first in-



a. b.

Fig. 4. a. Volvulus of the small intestine in a ten-year-old boy (barium meal, eight hours). b. Volvulus of small intestine in a man aged twenty-five (barium orally, nine hours).

stance, its passage can be shown by repeated roentgen examinations, in the second the obstruction is usually soon apparent and the diagnosis readily made (Fig. 2, a, b). However, it should be borne in mind that in some instances of obstruction due to strangulation the findings may be very similar to those of a simple occlusion (Fig. 3, a, b). The oral administration of barium is also very helpful in making the diagnosis of a volvulus of the small intestine (Fig. 4, a, b).

2. In many instances of obstruction the diagnosis is impossible both clinically and roentgenologically when the patient is first admitted. At all events he must be observed and during this time repeated roentgen examinations are the best means of making the diagnosis. The administration of barium orally is obviously more often indicated in the early than in the advanced cases.

a. b.

Fig. 5. a. True strangulation with obstruction (barium by mouth, two hours). Slow progression of contrast medium. Note small fluid levels in prestenotic loops and tumour-like density in mid-abdomen due to incarcerated loops. b. Contrast-filled loops are displaced by non-filled incarcerated loops (nine hours).

3. In our material the frequency of complete and incomplete obstructions is about equally divided. This corresponds with the results given by BECKER, who reported forty per cent partial and sixty per cent complete obstructions. When barium is used systematically all the incomplete obstructions are comparatively easily diagnosed and untimely operations avoided. The complete obstructions are also diagnosed with a high degree of certainty, a further important point being that in most instances true strangulation with obstructions may also be diagnosed correctly (Fig. 5, a, b).

In about fifty per cent of our cases barium by mouth has been used. The material now consists of 512 cases of complete mechanical small bowel obstruction examined during the last fourteen years. The value of our procedure is emphasized by the fact that the diagnostic failure has been only about five per cent. It has varied a little from year to year as is shown in Table 1.

Complete obstruction is generally correctly diagnosed, indicating the proper treatment which in nearly all cases is early surgical intervention. In most cases of partial obstruction the passage is re-established spon-

Table 1

Roentgen examination in small bowel obstructions

Number of diagnostic failures.

Years	Cases	Errors
1942	58	3
1943	48	3
1944	44	3
1945	42	0
1946	36	4
1947	35	2
1948	39	1
1949	32	4
1950	38	1
1951	32	0
1952	41	3
	445	24 = circa 5 %

taneously, and consequently no special treatment seems to be needed. When the obstruction has been complete, operation has in practically all cases confirmed that the surgical intervention has been the correct treatment. The block has usually been caused by strong adhesions or bands or by the bowel being kinked, twisted or incarcerated.

4. It is essential that the diagnostic problems are not limited to considerations only of bowel obstruction. Many other acute abdominal conditions may give initial findings which may be confused with mechanical obstruction, examples of which are: acute appendicitis, salpingitis, pancreatitis, cholecystitis, and regional enteritis. When barium is administered orally in such cases the roentgen examination may support the clinical diagnosis adequately (Fig. 6, a, b, c). It therefore seems difficult to obtain good diagnostic and therapeutic results in acute abdominal conditions if this procedure is not followed.

5. This attitude toward the problem is also based on the fact that our mortality rate in acute obstruction has gradually decreased over the years. Many factors may obviously have played a part, but the diagnostic problems are the most decisive and an early correct diagnosis is most important. When the cases from Department III are listed we arrive at the figures shown in Table 2. In this department (Director: Prof. C.

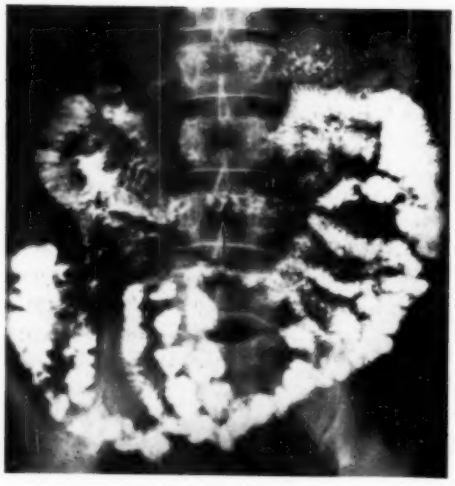
Table 2

Fatality rate in obstruction of small intestine. (*Department III.*) (*Courtesy* A. HOYER)

Mortality rate in cases of ileus.

Sm. int.	Total	Died	Fatality rate %
17 years, all	306	41	12.3 %
17 years, operated	300	33	11 %
1947—51, all	92	6	6.2 %
1947—51, operated	81	3	3.7 %

a. b.



c.

Fig. 6. Acute phlegmonous jejunitis: a. Routine film. b. Findings accentuated following barium, by mouth. c. Three weeks after antibiotic treatment. Some inflammatory changes persist in the upper jejunal loops.

SEMB) the treatment has remained almost unchanged during the period and well established according to the principles mentioned. Certainly, comparison of mortality rates are always difficult, but as far as can be gathered from the literature these figures are very low (cf. KROOK).

The comparison of the figures with the results obtained by suction treatment is also difficult (GOLDEN). It must be emphasized that the majority of our cases were verified at operation and were true cases of acute obstruction (or ileus).

6. In many instances barium also may be administered by mouth post-operatively when a condition of ileus is suspected. No harm to the patient has been experienced in such cases and the result is often of great help for the evaluation of the condition. One should remember that when barium has been given pre-operatively it may be followed and observed by roentgen examinations in the first days after the operation.

The administration of barium by mouth is, however, not indicated in all cases of obstruction. In small bowel obstruction it should be avoided under the following conditions:

a) When the diagnosis, based on clinical and roentgenologic examinations is certain.

b) When a roentgenologic examination shows definite signs of an advanced condition, especially when fluid or gas is present in the peritoneal cavity.

Risks and possible disadvantages

1. One may rightly object that in this method the observation period may be unnecessarily prolonged. We admit that this may have occurred in some instances, but on the other hand this drawback is more than compensated for by the general diagnostic precision. The low mortality rate seems also to prove that this attitude towards the problems is well founded. In recent years, when care has been taken on this point the risk of a too long observation period seems also to have been minimized. In doubtful cases an eight to twelve hours period of observation usually decides whether the stenosis is complete or not. For years we have tried the Miller-Abbott tube and suction treatment in acute obstruction, but this method has been abandoned due to the period of observation being too long and the uncertainty in revealing the condition as one of complete or incomplete obstruction. Suction treatment is used only in selected cases.

2. When barium is administered per os as a routine measure in acute abdominal cases one may run the risk of encountering cases of perforated ulcers, mistaken for obstruction. We have experienced five such cases without any fatal outcome. If the barium emulsion enters the peritoneal cavity it is obviously an alarming sign, but being easily recognized, does not appear to complicate the condition. Relatively small amounts have entered the peritoneal cavity and have not interfered with surgery (Fig. 7).

Fig. 7. Case of perforated duodenal ulcer (clinically suspected ileus). Some of the contrast medium has entered the peritoneal cavity.

3. Retention of barium in the large bowel in the post-operative period may sometimes occur. However, when the relatively small amount mentioned is used, this does not seem to interfere seriously with the passage through the large bowel. In some few cases retention of barium in the colon has effected some degree of obstruction in the post-operative period. These are cases with lesions in the colon examined by means of barium enemas. In cancer of the sigmoid for instance, barium may be retained proximal to the tumour and cause difficulty to the passage of the faeces. It is, therefore, advisable to give only small amounts of barium by mouth, especially if any is present in the colon beforehand. In the same way any considerable amounts of barium should if possible be evacuated from the colon before any operation on either the small or large bowel.

SUMMARY

In all doubtful cases of small bowel obstruction, an examination by means of barium administered by mouth should be carried out. It is an unharmful procedure which gives the best diagnostic possibilities, not only in obstruction, but also in the differential diagnosis of various other acute abdominal conditions.

ZUSAMMENFASSUNG

Alle auf Dünndarmileus verdächtigen Fälle sollten nach Verabreichung von Bariumkontrast per os untersucht werden. Es ist eine ungefährliche Prozedur, welche die besten diagnostischen Möglichkeiten erbietet und zwar nicht nur für Ileusfälle, sondern auch für die Differentialdiagnose verschiedener anderer akuter abdominaler Zustände.

RÉSUMÉ

Dans tous les cas douteux d'occlusion de l'intestin grêle, on devrait procéder à un examen par repas baryté. C'est une pratique sans danger qui donne les meilleures possibilités diagnostiques non seulement dans l'occlusion, mais aussi dans le diagnostic différentiel de diverses autres affections abdominales aiguës.

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FROM THE PAEDIATRIC ROENTGEN DIAGNOSTIC DEPARTMENT (DIRECTOR: S. R. KJELLBERG), KAROLINSKA SJUKHUSET, STOCKHOLM, SWEDEN

A CIRCULATION SYSTEM FOR KEEPING THE DEVELOPER CONSTANT

by

Sven Roland Kjellberg

The growing demand for more detailed roentgenologic diagnosis has greatly increased the importance of the quality of the roentgenograms. This is influenced by several factors, the developing process being one of the most important. With the technique in common use, the developer gradually undergoes a change; as a result, the quality of the film usually becomes successively poorer. Any improvement in the developing technique that would lead to the production of roentgenograms of uniform quality must therefore be regarded as of interest.

At Karolinska Sjukhuset, we have for about five years used a circulation system which permits development under constant conditions. It has proved possible with this apparatus (constructed with the technical assistance of the engineers SVEN OLSSON and IVAR NORDH) not only to keep the activity of the developer constant, but also to maintain the activity at the optimum level for a period of at least two months. These data are based on an average developing capacity of 25 m² of roentgen film per day.

As shown in Fig. 1, the developer, which is drawn off from the bottom of the developing tank, is driven by a centrifugal pump through both a thermostat and a filter. The thermostat keeps the developer at a constant temperature of 19° C with a variation of $\pm$ 0.1° C. The construction of the filter is simple; it is on the same principle as that used for straining milk. The straining web is of cotton; when the pressure of work is high, it is replaced every two or three hours. The replacement can be made without difficulty in the light of the dark room in less than one minute.

Briefly presented at a meeting of the Swedish Association of Medical Radiology, June 3, 1950; submitted for publication, Feb. 28, 1954.

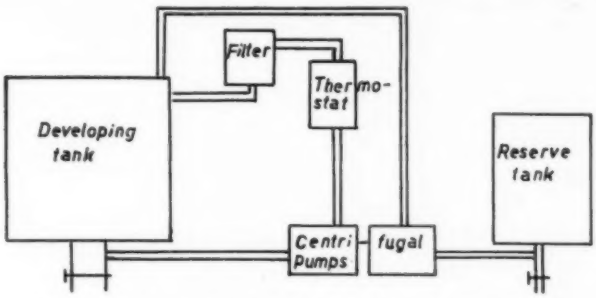


Fig. 1. Schematic drawing of the circulation system.

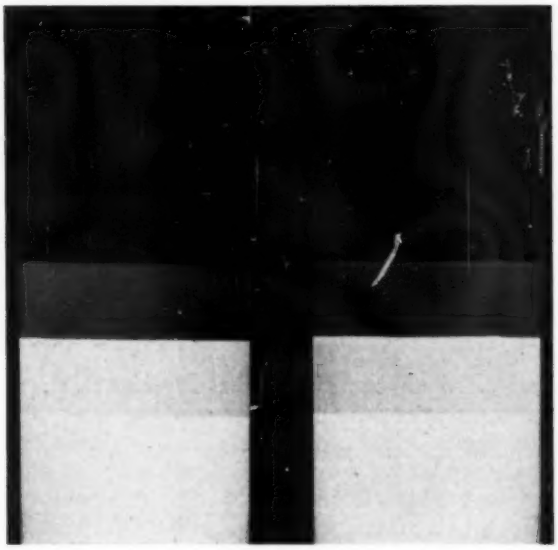
After passing through the filter, the developer is sprayed through small holes into the upper part of the developing tank, about one centimeter below the upper surface of the fluid. The direction of the jets is such that the developer is sprayed between the hanging films, thus keeping them apart. This eliminates the risk of developing stains produced by contact of the films with each other. The circulation pump is adjusted to allow complete circulation of the solution in the developing tank (130 litres) six to seven times an hour. Since the developer is in constant movement, the accumulation of bromide salts in the vicinity of the films is prevented. The effect is thus of the same nature as that on which rotation development is based.

The developing tank is also provided with a level relay. This controls a centrifugal pump, which pumps developing solution from the reserve tank into the main tank, when the level of the solution in the latter has fallen 3 to 5 mm.

The design of the circulation system allows either ordinary developer or replenisher solution to be used for refilling the tank.

If the former is used, it is necessary — in order for development to be constant — to drain off from the tank a quantity of circulating developer per time unit which corresponds to the quantity consumed. This is, on broad lines, proportional to the surface of film developed. Experiments made in our department have shown that a drainage amounting to 1 litre of developer per 0.5—1 m^2 of film is suitable. The system is provided with an adjustable outlet cock to regulate the drainage.

Experiments were also made with draining off every morning a quantity of developer corresponding to the daily consumption, instead of a continuous outflow. The aim was at the same time to remove the sediment which forms when the circulation has been shut off during the night. No definite difference could be noted between the results of these two procedures. In both cases, the older the developer, the



a. b.

Fig. 2. Density curves recorded in connexion with renewal of the developer; a) immediately before draining off the two-month-old developer, b) freshly prepared developer.

greater was the tendency for deposits to form in the pipes and tubes of the system. In addition, an increasing yellow staining of the film and of the fixing bath occurred towards the end of the period.

Considerably better results were obtained with the use of a replenisher (the replenisher mainly used was Gevaert G 230) for refilling the tank without draining off the developer. It was, however, found that the replenishers on the market brought about a successive change in the activity of the developer. As a rule, this consisted of an increase in the developing activity, together with slight discoloration of the films and an increase in the basal fog. After a series of experiments, it proved possible to keep the activity of the developer practically constant for a period of two months by refilling the tank with a mixture of ordinary developer and replenisher (G 230) in a proportion of 1 : 3. This applied with a consumption corresponding to 25 m² of film developed per day.

During the past few years, the developer has been renewed every two months. This has not been on the grounds of any change occurring in the activity of the developer, but because flushing and cleaning both of the developing tank and of the pipes and tubes of the circulation system

were found to be expedient; in this way, deposits on the walls have been prevented. In connexion with these renewals, density curves were recorded both of the old and of the new developer. No measurable difference could be noted between the respective curves (Fig. 2).

SUMMARY

An account is given of a circulation system for producing constant development of roentgen films. With a daily development of 25 m² of film, renewal of the developer is required at the most every two months.

ZUSAMMENFASSUNG

Ein Bericht über ein Zirkulationssystem zur Erzeugung von konstanter Entwicklung von Röntgenfilmen wird abgegeben. Bei täglicher Entwicklung von 25 m² Film ist eine Erneuerung des Entwicklers höchstens jeden zweiten Monat erforderlich.

RÉSUMÉ

L'auteur présente un système de circulation destiné à donner un développement constant des films radiographiques. Le développement quotidien de 25 m² de film ne nécessite le renouvellement du révélateur que, tout au plus, tous les deux mois.

FROM THE ROENTGENDIAGNOSTIC DEPARTMENT (DIRECTOR: PROFESSOR OLLE OLSSON) OF THE UNIVERSITY CLINICS OF LUND, SWEDEN

RENAL TUMOUR NOT DEMONSTRABLE BY UROGRAPHY BUT SHOWN BY RENAL ANGIOGRAPHY

by

F. Olov Löfgren

In the diagnosis of renal tumours it is usually considered that if excretion urography shows no signs of morphologic changes, the presence of a tumour may be excluded.

In 1946, Sven Johnsson published the material from our department, which at that time comprised 87 cases of renal tumours examined urographically. Pathologic changes in the radiogram were observed in all cases except one. This was of a hazelnut-sized nephroma which had not given any clinical signs, situated in the outer margin of the kidney. He finished the survey of the reliability of roentgen diagnosis with the following words: "If a nephroma is suspected clinically, this diagnosis cannot be discarded completely even if the radiologic examination shows normal conditions. In such cases a second examination should be performed after some time." In order to avoid loss of valuable time renal angiography may in such cases be carried out immediately and perhaps reveal a tumour.

During the last few years we have performed renal angiography in most cases in which urography has shown an expansive process, in order to distinguish tumours from cysts. The tumour will be visualized by the presence of pathologic vessels of varying appearance, and the accumulation of contrast medium in the tumour will differ in density from that in the normal renal parenchyma. It is, therefore, also possible to demonstrate tumours which, owing to their small size and situation, do not deform the renal pelvis and are therefore not shown urographically. It may be of interest to describe a case in which renal angiography demonstrated the presence of a renal tumour which was not revealed by urography.

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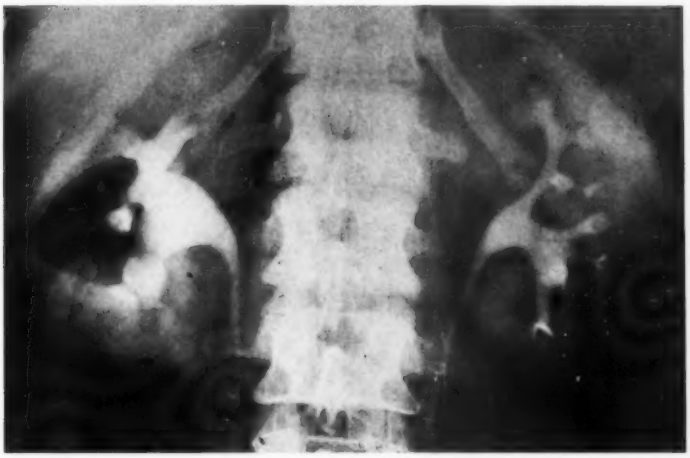

Fig. 1. Urography. Small bulge in the upper part of the lower half of the right kidney. No pathologic signs in the left kidney.

A case of this type was recently reported by OLHAGEN.

The patient was a man, aged 47, with a 2 years' history of irritating cough, fatigue, hypochromic anaemia and increased sedimentation rate. In the course of just over 1 year he was examined urographically on 6 occasions, but in none of the films were there any signs of a tumour. No roentgenograms were published, but the urographic examinations were performed by a skilled radiologist. On account of the extreme changes in the electrophoretic pattern of the plasma, a tumour was nevertheless suspected and renal angiography was carried out. The films showed a hypernephroma in the upper pole of one of the kidneys. Operation revealed a hypernephroma almost the size of a mandarin, one third of which was situated sub-capsularly and the rest surrounded by renal parenchyma.

Case Report

In our case the patient was a woman (k/j 950914/53), aged 58, who had had hypertension for 6 years. After about 6 months' pain in the left hip, a spontaneous fracture of the neck of the femur occurred and she was admitted to the University Clinics, Lund. Roentgen examination of the left hip showed an osteolytic process with a petrochanteric fracture. The changes were considered as being due to metastases. The patient had never had pain in the region of the kidneys and had not had hematuria. The urinary sediment was normal. Erythrocytic sedimentation rate (WESTERGREN): 18 to 25 mm. Excretion urography, performed in an attempt to find the primary tumour, showed a bulge in the medial contour of the lower part of the right kidney (Fig. 1). As it was thought that this bulge might represent a small tumour but on the other hand be only an anatomic variant, renal angiography was performed (ad modum SELDINGER by the introduction of a plastic catheter into the femoral artery. 30 ml Umbradil 60 % was injected. Ten exposures were made at a rate of 1 exposure per second.)

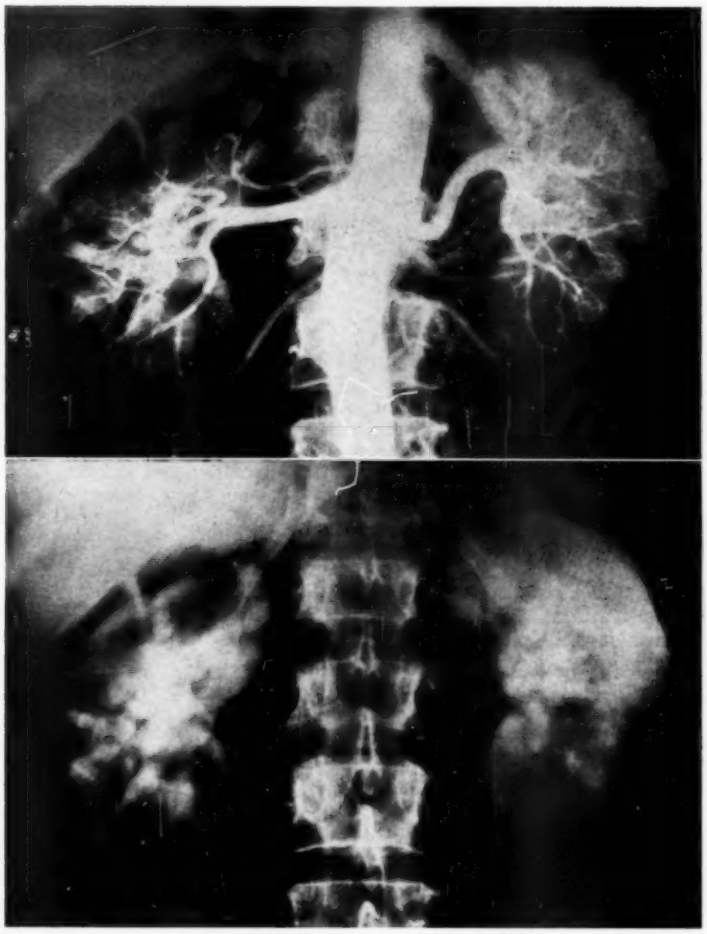

Fig. 2. Renal angiography. Above arterial phase; below nephrography, late stage. Normal vascular pattern and accumulation of contrast medium in the right kidney. The bulge in the medial part of the lower part of the right kidney represents an anatomic variant. A large artery runs to pathologic vessels in the medial part of the upper pole of the left kidney. At a later stage the accumulation of contrast medium in this area is less dense than in the normal parenchyma. A richly vascularized small tumour in the upper pole of the left kidney.

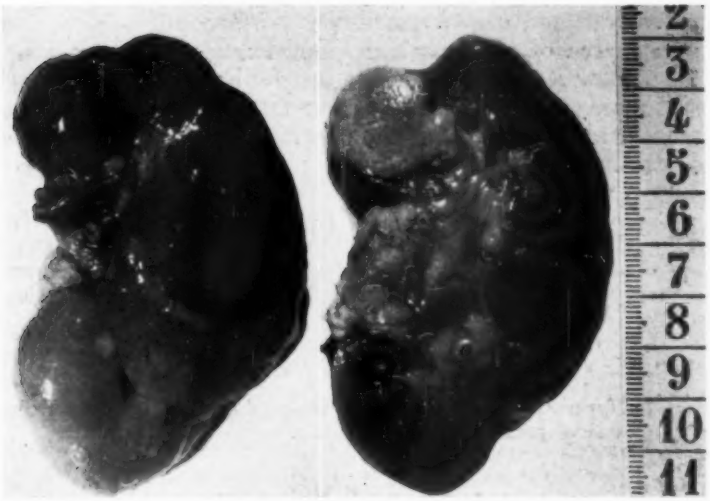

Fig. 3. Operative specimen: Left kidney. Tumour medial in the anterior of the upper pole, mainly sub-capsular and not deforming the outline of the adjacent calyx.

The pattern of the vessels supplying the suspected region in the medial part of the right kidney was normal, as was the appearance of the accumulation of contrast medium in the renal parenchyma. The medial bulge was due to renal parenchyma and represented an anatomic variant. A large artery, however, ran to the upper pole of the left kidney where, in an area measuring 2.5 × 3 cm filling of pathologic vessels was obtained. From here the contrast medium passed rapidly into the renal vein, and in a later phase the accumulation of contrast medium in this region was less dense than in the normal renal parenchyma (Fig. 2). The examination thus showed a richly vascularized small tumour in the medial part of the upper pole of the left kidney. The patient was operated on in the Department of Surgery, Lund. At operation it was difficult to palpate the tumour demonstrated in the angiogram, but as the angiographic finding was convincing, the kidney was removed together with the fat capsule. Examination of the extirpated kidney showed a rounded hypernephroma medially in the upper pole. The growth, which measured 2.5 × 3 cm in cross-section, was situated mainly sub-capsularly and was to a slight extent surrounded by renal parenchyma. The major part of the tumour was situated in the anterior part of the kidney and protruded only 12 mm beyond the normal outline in the frontal plane. No sign of necrosis was seen (Fig. 3). Pathologic findings: nephroma of Grawitz's type.

Like the case described by OLHAGEN, this case showed that the normal appearance of the urogram does not exclude the presence of a tumour. In both cases the tumour was situated mainly sub-capsularly and did not deform the outline of the renal pelvis. This position in combination with small size makes the tumour undetectable by urography. Angio-

graphy, however, provides a possibility of detecting tumours, even if small, irrespective of their position. Renal angiography can, however, hardly be a routine examination like urography; it is more complicated and carries more risk. If there is a strong reason to suspect renal tumour despite a normal appearance of the urogram, renal angiography should, unless contra-indicated, be performed.

SUMMARY

A case of a small hypernephroma not shown by urography but demonstrated by renal angiography is described to illustrate the value of this additional method in doubtful instances.

ZUSAMMENFASSUNG

Ein kleines Hypernephrom mit normalem Urographiebefund, aber mit einem pathologischen renalen Angiogramm, wird beschrieben.

RÉSUMÉ

Pour illustrer l'intérêt de cette méthode dans les cas douteux, l'auteur présente un cas de petit hypernéphrome que ne montrait pas l'urographie et que mit en évidence l'angiographie rénale.

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FROM THE ROENTGEN DEPARTMENT (DIRECTOR: PROFESSOR D. J. STEENHUIS),
THE ACADEMIC HOSPITAL, LEIDEN, HOLLAND

A 20 CURIE TELECOBALT UNIT

by

J. H. Mellink

In 1952 a home-made 20 curie cobalt unit was installed in the Roentgen Department of the Academic Hospital of Leiden University. The radioactive cobalt was produced in the nuclear reactor at Oak Ridge, Tennessee, U. S. A. The design of the treatment head, which has a capacity of up to 100 curies cobalt 60, and of the applicators, the loading of the unit, as well as the measurement of the depth dose will be described in this paper.

Design and mounting of the treatment head. A diagram of the treatment head is shown in Diagram 1. The head, weighing over 900 kilograms, consists of two concentric spheres. The outer steel-encased lead sphere *O* is 54 cm in diameter and the inner lead sphere *I*, 20 cm in diameter, the latter lying in a spherical cavity (20.8 cm in diameter) in the outer sphere. The cobalt 60 source is situated in a hole on the surface of the inner sphere. The apparatus which is shown in the 'on' position in Diagram 1, may be 'turned off' by rotating the inner sphere through 180° about axis A. This introduces 19.5 cm lead into the path of the radiation. The rotation of the axle A which is supported by ball bearings at both ends, is achieved by means of an electric motor N (Diagram 1 and Fig. 1) and gears (not shown in the figures). The angle through which the inner sphere may rotate is fixed at exactly 180° by means of two limiting switches. As may be seen from Diagram 1, the motor N is fixed to the surface of the outer sphere.

The outer sphere consists of two hemispheres fixed together with 28 screws and is flattened on both sides and at the bottom. A conical orifice in the outer sphere permits the passage of the gamma radiation when the inner sphere is in the 'on' position. The plane surfaces of the outer sphere

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are covered with steel plate of 6 mm thickness, the remaining surface of this sphere having a steel covering, 3 mm in thickness.

The treatment head (*i. e.* the outer and inner spheres together) possesses three independent free movements. Rotation of the treatment

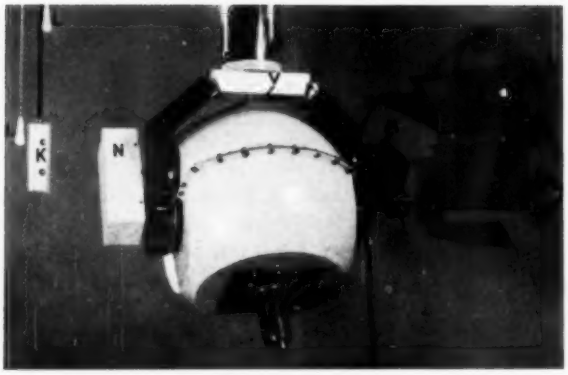

Fig. 1. Photograph of the unit.

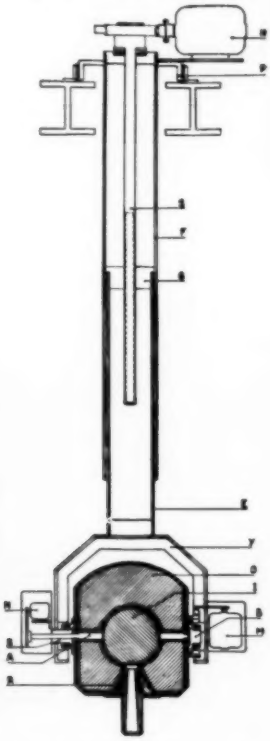

Diagram 1. Diagram of the unit.

head about the horizontal axle B is effected by an electric motor M (Diagram 1 and Fig. 1) and gears (not shown). The axle B is supported by ball bearings at both ends; one extremity is pierced in order that a connection between the axle A and the motor N may be made. The motor M may be energized by means of the push-button control panel D on the cross-piece Y (Fig. 1), whereas the direction of the rotation of the head is controlled by the commutator switch C. From Fig. 1 it may be seen that the motor M is fixed to the cross-piece Y which supports the treatment head.

The cross-piece Y is supported by the hollow cylindrical tube E which has a large female screw G at its upper end. This tube may move in a telescopic fashion in relation to the hollow cylindrical tube F; this latter is closed at its upper end by the cylindrical plate P which rests on 8 wheels. These 8 wheels move along a circular rail supported by two iron beams about 50 cm below the ceiling. Rotation of the apparatus about its vertical axis is thus possible and may easily be performed by hand.

The axle S (Diagram 1) is provided with a screw-thread which fits into the female screw G, and is supported by ball bearings resting on plate P. The axle S may thus be rotated by means of a motor H (Diagram 1) fixed to plate P, and a worm gear. A vertical movement of the treatment head is obtained by energizing motor H and by the incorporation of two limiting switches does not exceed 60 cm. The motor is switched from the small push-button control panel K (Fig. 1) suspended from the ceiling. Should it be found impossible to switch off the motor at the moment desired owing to a possible short-circuit in the control panel, use may be made of the emergency switch L (Fig. 1).

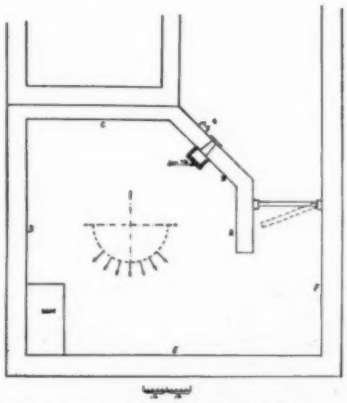

Diagram 2. Plan view of the treatment room.

Treatment room. A plan view of the treatment room is shown in Diagram 2. The concrete inner walls A and C are 30 cm thick as is the concrete outer wall D. The concrete inner wall B is 35 cm thick whereas the brick outer walls E and F have a thickness of 44 cm. There are no windows in wall E. The windows in walls D and F measure only 50 cm in height and are situated more than 250 cm above the floor. The door to the treatment room is faced with 4 mm lead.

Observation of the patient during irradiation is made possible by means of a periscopic mounting with two plane mirrors and a small hole in wall B about 150 cm above the floor level. One of these two mirrors which are mounted in the treatment room, is shown in Fig. 1. The other mirror is situated near the hole in wall B and is not seen in the figure, owing to its being hidden by a 6 cm lead shield which is placed in front of the hole in order to prevent any leakage of radiation. Lead glass covers the other side of the hole. Motor N (Diagram 1) is switched from the control panel G (Diagram 2) which is attached to wall B near the hole. It takes 6 seconds to rotate the inner sphere through 180 degrees. The position of the cobalt

source on the surface of this sphere is indicated by red and green lights on the control panel.

Loading the head. The radioactive cobalt having a specific activity of about 5 curies per gram arrived in November 1951 at the Institute for Nuclear Research in Amsterdam. The material was supplied by the nuclear reactor at Oak Ridge in the form of 19 cylinders each about 3 mm

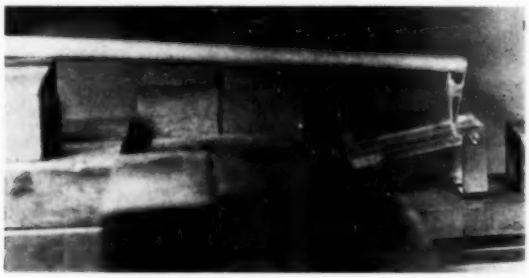

Fig. 2. Photograph of perspex source container partly filled with dummy cylinders. One cylinder is being released on a slide at the end of which it will fall automatically in the hexagonal hole.

in diameter and about 3 mm long and having an activity of approximately 1 curie. At our request, Professor A. H. W. ATEN (of the Institute for Nuclear Research) measured the activity of each radioactive cylinder. Thirteen of these cylinders had an activity of between 1.22 and 1.14 curies. The activities of the other 6 cylinders showed larger differences, namely from 1.26 to 0.87 curies.

The radioactive cobalt was shipped to Leiden in a lead safe from which it was transferred to the safe of the treatment room (Diagram 2). The head was loaded in two stages. The cylinders were first placed in a source container specially constructed for this purpose, and the filled source container was then fixed into the hole on the surface of the inner sphere.

The source container (Diagram 3) consists of a stainless steel cylinder, 3.5 cm in diameter and 0.5 cm in height. A hexagonal hole 0.35 cm in depth, into which the 19 radioactive cylinders fit exactly is machined in the container. The cylinders were transferred one by one from the safe into the source container with the help of a specially constructed pair of tongs 2 metres long. The operator was protected by a lead wall more than 15 cm thick between him and the source container. In order to reduce the filling time as much as possible, we previously practised with dummy cylinders and a perspex source container. In Fig. 2 a phase of one of these trials is shown: nearly all the cylinders are already in the source container. One cylinder has just been transferred from the safe and released onto a slide at the end of which it will fall automatically into the hexagonal hole.

After the hole had been filled it was closed with plug P. The source container was then inserted into the treatment head with help of a rod, 2 metres long, and furnished at its end with two thin conical rods which fit exactly into the two holes B. A second operator fixed the source container into the hole on the surface of the inner sphere by driving home two screws into bore-holes in the inner sphere with the help of a screwdriver (also

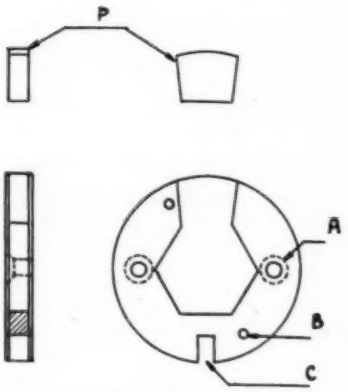

Diagram 3. Diagram of source container.

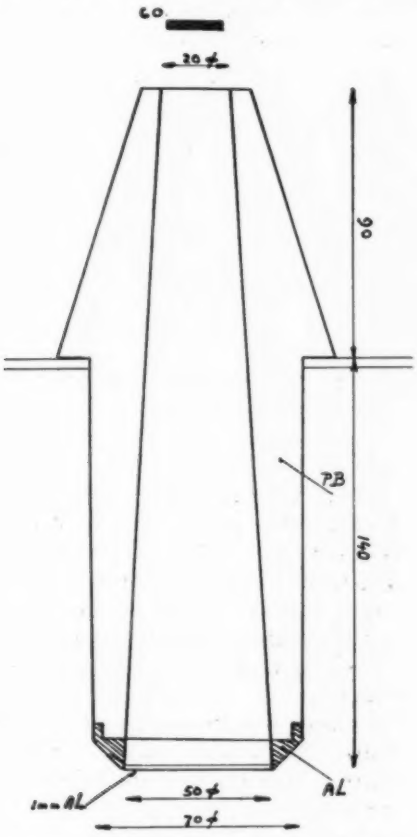

Diagram 4. Diagram of the applicator with source-skin distance of 25 cm.

2 metres in length). The time of insertion and fixation was shortened considerably by previously placing a guiding screw near the circumference of the hole in the inner sphere in such a way that provided it registered with hole C, the two holes A exactly faced the corresponding bore-holes in the inner sphere.

None of the four operators engaged on the loading of the head received a dose of more than 0.4 r. As the dimensions of the treatment head per-

mit, we hope to load it with 100 curies before long. We are planning to improve the method of insertion so that the operators will be still better protected.

Applicator design. Owing to the rather small output of the unit the source-skin distance can be only 25 cm at the most. The diaphragm-skin distance should therefore be rather short in order to prevent the penumbra from becoming too large. Two applicators have been constructed to date. One of these (Diagram 4) which is used for the treatment of laryngeal carcinoma, has a source-skin distance (s.s.d.) of 25 cm and a circular irradiation field 5 cm in diameter. The other applicator which is used for experiments in animals, has a s.s.d. of 15.5 cm and a circular field 2 cm in diameter.

The applicators are constructed in such a way that the diaphragm has a thickness of at least 8 cm outside the irradiation field. Lest the applicators should be too heavy a part of the conical orifice in the outer sphere is permanently closed by a lead intermediary piece R (Diagram 1) held in place by means of a steel plate screwed on to the bottom on the outer sphere. The intermediary piece weighs about 10 kilograms and has a conical hole in which the applicators just fit. This hole is closed at its narrower end by a sheet of 1 mm perspex in order to prevent cobalt dust from escaping should anything happen to the source container.

Diagram 4 shows the applicator with a s.s.d. of 25 cm. This applicator weighs about 7 kilograms and is fitted with a steel plate which may be fixed to the bottom of the outer sphere. It will be noted that the diaphragm-skin distance is only 1 cm. JOHNS, EPP, CORMACK and FEDORUK (1952) state that the gamma-ray beam is contaminated with electrons. These electrons come from the source container, the conical hole in the applicator and the diaphragm. If the diaphragm-skin distance is about 20 cm the contamination of the gamma-ray beam with electrons is minimal. In order to reduce the contamination with electrons as much as possible the conical holes in our applicators are closed with aluminium plates 1 mm thick. Moreover, a 1 cm plate of aluminium lies between the diaphragm and the skin.

The treatment head is fitted with a back pointer (not shown in Fig. 1) in order to facilitate directing the beam onto the patient.

Measurements of depth dose

Methods of measurement. The dose measurements were made in a masonite phantom with a density of 1.02 g/cm³. This phantom was 40 cm long, 40 cm wide and 40 cm high. The gamma-ray beam was mostly directed vertically onto the phantom. Several holes were machined in a few boards of the phantom, suitable for containing either Victoreen

condenser r-chambers (25 r and 100 r) or small Baldwin ionization chambers Type B.D. 2. As these boards could be incorporated in the phantom at any arbitrary height, the measurement of the dose at many points was possible.

Output and surface dose. Victoreen ionization chambers were used to measure the output of the unit. In order to establish electronic equilibrium, bakelite caps of 1 mm thickness were placed over the chambers. In March 1953, the air dose rate was 5.0 r/min. at a distance of 25 cm from the source.

We made no attempt to measure the surface dose rate or the build-up ratio. One may expect that with our applicators the build-up ratio will be very nearly unity and that the maximum will occur close to the surface, by reason of both the short diaphragm-skin distance and the short source-skin distance (compare the measurements of JOHNS, EPP, CORMACK, FEDORUK, 1952 and those of MEREWETHER, OSBORN, WYARD, 1952).

We extrapolated the surface dose from the measurements of the depth dose obtained both with the Victoreen ionization chambers and the Baldwin Type B.D. 2 chambers. In March 1953, the surface dose rate of the applicator with a s.s.d. of 25 cm amounted to 5.0 r/min. and was thus practically equal to the air dose rate. The contribution of backscatter may consequently be neglected for the small irradiation fields used by us. This is in agreement with the measurements of backscatter given by DIXON, GARRETT and MORRISON (1952).

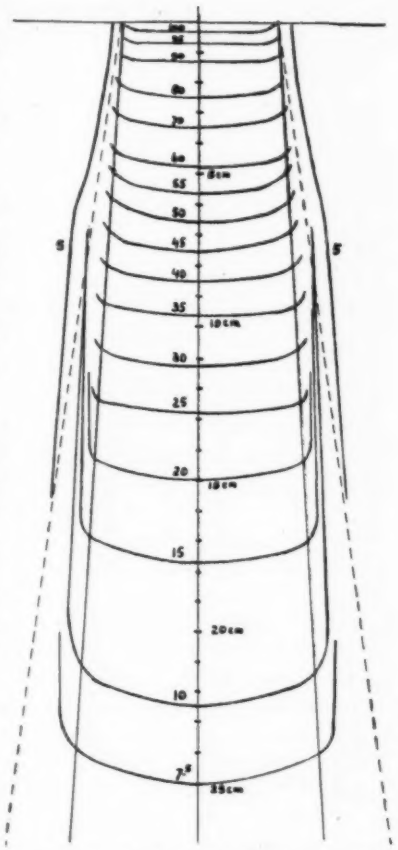

Diagram 5. Isodose distribution for Co^{60} radiation in a masonite phantom for a circular field 5 cm in diameter and a source-skin distance of 25 cm. The region of penumbra is marked by full lines on the inner side and by dotted lines on the outer side.

According to the measurements of Professor ATEN, the 19 cylinders together had an activity of 21.6 curies in November, 1951. Taking into account the radioactive decay of the cobalt 60, the self-screenage of the source (amounting to about 8 % as computed by means of Wilson's

formula, 1951), and the screenage by the stainless steel of the source container, as well as by the perspex cover on the intermediary piece and the aluminium plate on the applicator, we may compute that the air dose rate should be between 5.4 and 5.5 r/min. at a distance of 25 cm from the source. The measured value is thus about 8 % lower than the calculated value. A considerable part of this discrepancy may presumably be ascribed to the loss of an unmeasured and therefore unknown quantity of radioactive cobalt 60 as the consequence of an accident with our first source container.

Percentage depth dose and isodose distribution. Dose measurements on the central axis have been performed with the Victoreen ionization chambers for depths between 1.2 cm and 25 cm and with the small Baldwin ionization chambers for depths between 0.3 cm and 25 cm. The results of these measurements are given in Table I, columns 2 and 5.

Table I

Percentage depth dose for Co^{60} radiation

Depth (cm)	s.s.d. = 25 cm circular field 5 cm in diameter field size 19.6 cm²			s.s.d. = 15.5 cm circular field 2 cm in diameter field size 3.1 cm²	
	values measured in masonite phantom	values calculated by LAMERTON for a water phantom	values calculated from the data of JOHNS et al. and of DIXON et al.	values measured in masonite phantom	values calculated from the data of JOHNS et al. and of DIXON et al.
0	(100)			(100)	
0.3	100			97	
0.6	97			93	93
1.2	91		92	82	84
2.0	84	82	83	72	73
3	75		74	61	61
4	67	65	66	53	52
5	59		59	46	
6	53	54	52	39	37
7	48		47	34	
8	43	44	42	29	28
9	38		37	26	
10	34	35	33	22	21
11	31			19	
12	27	28	26	17	16
13	24			15	
15	20	20	19	12	11
17	16			10	
20	12	13	11	7	6
25	7½				

The isodose distribution has been measured with the small Baldwin ionization chambers. Diagram 5 shows the isodose curves obtained for the applicator with a s.s.d. of 25 cm and a circular field 5 cm in diameter.

Discussion

We have compared our measurements of the percentage depth dose with the theoretical computations of LAMERTON (1948) as well as with the measurements of several investigators. One of the topics discussed by LAMERTON in his paper was the percentage depth dose along the central axis in a water phantom irradiated by gamma-radiation from cobalt 60 for a source-skin distance of 25 cm and several field sizes. Some of the results of his calculations (given in Fig. 22 of his paper) are inserted in column 3 of Table I; as may be seen, the agreement between our measurements and the calculations of LAMERTON is satisfactory.

LAMERTON in his paper also predicts that the variation of the percentage depth dose with the source-skin distance is given very approximately by the 'F' factor, especially for small irradiation fields. The 'F' factor is obtained directly from the inverse square law (MAYNEORD and LAMERTON, 1941). JOHNS, EPP, CORMACK and FEDORUK (1952) have already confirmed this prediction for source-skin distances between 50 and 100 cm. We have made an attempt to extend their investigations to smaller values of s.s.d. For this purpose we converted, using the "F" factor, the depth dose data obtained by JOHNS, EPP, CORMACK, FEDORUK (1952) and by DIXON, GARRETT, MORRISON (1952) for a source-skin distance of 60 cm into data for the source-skin distances used by ourselves as well as by MEREWETHER, OSBORN, WYARD (1952) and LIDÉN (1952). The "F" factor used for this conversion is $\left(\frac{f}{60} \times \frac{60+d}{f+d}\right)^2$ where f = source-skin distance and d = phantom depth in cm. The results of these calculations are given in Table I, columns 4 and 6, and in Table II, columns 3 and 5. As may be seen, it seems that for small areas the "F"

Table II

Percentage depth dose for Co^{60} radiation as measured by several investigators

Depth (cm)	s.s.d. = 8 cm field size 28 cm²		s.s.d. = 6.5 cm field size 28 cm²	
	values measured by MEREWETHER et al.	values calculated from the data of JOHNS et al. and of DIXON et al.	values measured by LIDÉN	values calculated from the data of JOHNS et al. and of DIXON et al.
2	60	62	62	57
4			40	35
5	34	32		
6			27	22
8	20	18	18	15
10			14	10
12			10	7
14	10	7	8	5

factor may be used for all depths and for all source-skin distances between about 15 cm and 100 cm without introducing any appreciable error. For smaller distances between source and skin, however, the variation of the percentage depth dose is somewhat less than predicted by the "F" factor, especially for larger depths. Perhaps a part of these (rather small) discrepancies (see Table II) may be ascribed to the fact that neither in the measurements of LIDÉN, nor with those of MEREWETHER, OSBORN and WYARD, were the dimensions of the cobalt 60 source negligible in comparison with the source-skin distances.

Protection

Some measurements of stray radiation have been performed with Baldwin ionization chambers Type B.D. 11 as well as with the Ekco radiation monitor Type 1118 A.

If the inner sphere of the unit is in the 'off' position the dose rate is less than 2 mr/hour over the whole surface of the treatment head except for a small area of the outer sphere nearest to the source. The dose rate on this small area amounts to 6 mr/hour. There are therefore no serious objections to loading the head with about 100 curies in the near future.

Though the treatment head may be rotated about its vertical axis through an angle of nearly 360°, the beam of radiation is only directed to the floor or in the general direction of wall E as indicated by the seven arrows in Diagram 2. If a patient is irradiated under these conditions, the dose rate is less than 1 mr/hour everywhere outside the treatment room except close to the area of wall E onto which the direct beam is pointed. Near this area the dose rate may be as high as 12 mr/hour. As the outer walls D, E and F are bound by a large grass lawn this high dose rate causes no radiation hazards.

Acknowledgements

The author gratefully acknowledges the considerable task performed by the personnel of the workshop of the Roentgen Department of the Academic Hospital in constructing the telecobalt unit described above. Mr. TH. KLEIN, in charge of this workshop, especially has had an important share both in the design and the mounting of the treatment head as well as in the solution of the difficulties encountered during the preparation of its loading. Appreciation and thanks are also tendered to Professor A. H. W. ATEN for performing the rather dangerous task of measuring the radioactivity of the cobalt cylinders.

SUMMARY

A description is given of the design and the mounting of a home-made 20 curie telecobalt unit which can contain up to 100 curies Co^{60}, now in operation at the Roentgen Department of the Academic Hospital of Leiden University. Dose measurements have been performed in a masonite phantom for two applicators with small irradiation fields

and source-skin distances of 25 and 15.5 cm respectively; these agree satisfactorily with the values of the percentage depth dose predicted theoretically by LAMERTON. From a provisional comparison of the measurements with those of several other investigators it may apparently be concluded that for small areas the 'F' factor (MAYNEORD and LAMERTON) may be used for all depths and for all source-skin distances between about 15 cm and 100 cm without introducing any appreciable error.

ZUSAMMENFASSUNG

In der Röntgenklinik des akademischen Krankenhauses in Leiden ist eine 20 Curie Telekobalt-Apparatur gebaut worden, die bis zu 100 Curie Co^{60} enthalten kann. Der Verfasser beschreibt die Konstruktion und die Montierung dieser Apparatur. Die Tiefendosis wurde in einem Masonitphantom für zwei Bestrahlungstuben mit kleinen Bestrahlungsfeldern und mit Fokus-Haut-Abständen von bzw. 25 cm und 15.5 cm gemessen. Diese Messungen zeigen eine befriedigende Übereinstimmung mit den Tiefendosiswerten, die LAMERTON theoretisch angegeben hat. Aus einem provisorischen Vergleich der Messungen mit den von anderen Forschern gefundenen Werten scheint man schliessen zu können, dass man bei kleinen Bestrahlungsfeldern für alle Tiefen und für alle Fokus-Haut-Abstände zwischen 15 cm und 100 cm mit dem »F«-Faktor rechnen darf (MAYNEORD und LAMERTON), ohne dabei merkliche Fehler zu begehen.

RÉSUMÉ

L'auteur décrit le schéma de principe et le montage d'un appareil de télécobaltthérapie qui peut contenir jusqu'à 100 curies de Co^{60}, construit dans la Clinique Radiologique de l'Hôpital Universitaire de Leyde, où il fonctionne actuellement. La répartition de la dose en profondeur a été mesurée dans un fantôme en masonite pour deux localisateurs avec de petits champs d'irradiation et des distances focus-peau de 25 cm et 15.5 cm respectivement. Nos résultats concordent de façon satisfaisante avec les valeurs de la dose en profondeur prévues théoriquement par LAMERTON. D'une comparaison des résultats avec ceux d'autres chercheurs on peut, semble-t-il, conclure qu'il est permis d'utiliser le facteur «F» (MAYNEORD et LAMERTON) pour toutes les profondeurs et toutes distances focus-peau comprises entre 15 et 100 cm sans commettre d'erreur importante, à condition que les champs d'irradiation soient petits.

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TREATMENT OF THE CORNEA WITH A NEW LILLIPUT ROENTGEN TUBE

by

P. J. L. Scholte, C. C. Kok-v. Alphen and *B. Combée*

The roentgen tube used for the investigations described in the present paper is probably the smallest ever designed (Fig. 1). Including the earthed jacket, it is 45 mm long and 14 mm in diameter. A power of 2.5 watts can be dissipated continuously at the anode, the maximum tube voltage being 25 kV, and the maximum tube current 200 μA.

Fig. 2 shows a schematic sectional view of the tube. The simplicity and compactness of design are chiefly due to the fact that the roentgen rays leave the tube via the anode, which consists of a very thin layer of gold deposited on a vacuum-tight plate of beryllium. Due to the relatively high atomic number of gold (79) a high efficiency of roentgen production is obtained from the electrons slowed down in it and owing to the very low atomic number of beryllium (4) the soft radiation excited at 25 kV will be transmitted with negligible attenuation.

The 'inherent filter' of the roentgen tube, *i. e.* the filter through which the roentgen rays, produced by the tube designed as described, must pass before their practical application, is equivalent to about 1.5 mm beryllium. The importance of this very low inherent filter will be discussed presently.

The beryllium plate is soldered to a metal bush which functions as the wall for this end of the tube ('anode can'). This metal anode assembly is earthed and the cathode connected to high voltage. The cathode comprises a filament, consisting of a tungsten coil of a few turns, and a small metal cylinder enclosing the filament and its supporting poles. (For further details see BOTDEN et al., 3.) The cylinder has a focusing effect on the electrons emitted by the filament. Moreover, it simplifies the problems of insulation between the cathode and the closely adjacent

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earthed jacket; without the cylinder the electric field strengths at the thin leading poles would be much higher than they now are.

The focus and the radiation obtained. A description of a roentgen tube is not complete without some remarks regarding the configuration and the loading of the focal spot. In this case it is most appropriate to begin with some general observations, which will also explain the choice of the constructional principle adopted.

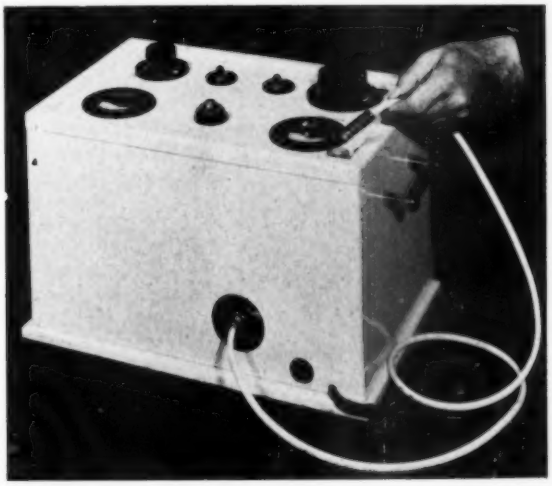


Fig. 1. The apparatus with the Lilliput roentgen tube.

Soft radiation is suitable for the therapeutic irradiation of very thin layers of tissue on or at the surface of the body; the underlying healthy tissue receives only relatively small doses and is consequently very little affected (small depth penetration). Owing to the low voltage and the very small inherent filter, the radiation of the tube is extremely soft; the half value thickness of the radiation is only 0.035 mm of aluminium or 0.5 mm of tissue at a tube voltage of 25 kV, and at 10 kV it is but 0.02 mm of Al or 0.3 mm of tissue. In this respect the radiation is similar to that of the present Philips CT tube with a window of mica and beryllium.

A second means of obtaining a very small depth penetration is to place the focus of the roentgen tube at a very short distance from the skin. This is extensively commented on in the article of HAZEU et al. (7). These authors further stated that the smallest focus—skin distance, and therefore the smallest relative depth doses can be realised if the anode

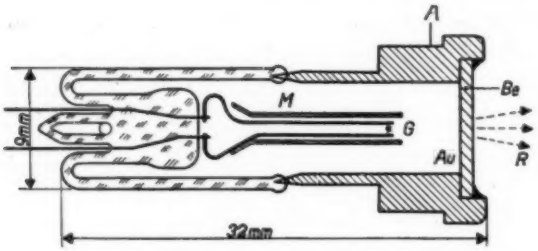


Fig. 2. Schematic cross-section of the KT tube. A anode can, Be beryllium plate, Au gold layer, G filament, M metal cylinder, R effective roentgen beam.

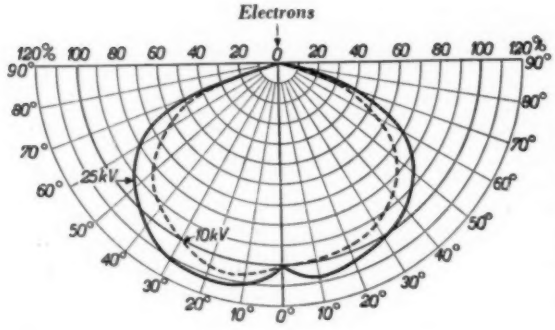


Diagram 1. Relative dosage rate of the KT tube, measured in different directions from the axis at a distance of 150 mm from the focus for two different tube voltages. In the axial direction (0°) the dosage rate for both curves is made equal to 100. The asymmetry may be due to a slight inhomogeneity of the gold layer. (These measurements and those of Diagr. 2 were made by W. J. OOSTERKAMP and J. PROPER.)

itself serves as the exit window for the radiation. This design principle also leads to a relatively simple tube construction. It is generally considered to be a drawback to this principle of design that the rays passing obliquely through the anode are attenuated more than those passing through perpendicularly, resulting in a strong decrease of the dosage rate from the centre to the edges of the irradiated area. This makes it difficult to apply an exact dosage of radiation. For this reason a different design was chosen for the CT tube, as may be seen in the article mentioned.

We have, nevertheless, already observed that a design with the anode functioning as window was chosen for the KT tube. This does not imply, however, that the objection referred to above was ignored; surprisingly enough this objection does not hold in this case. If the radiation intensity of the KT tube is measured in various directions (OOSTERKAMP and PROPER, 13) a diagram as shown in Diagram 1 results. The intensity by no means decreases with increasing deviation from the axial direction, but even increases initially; at an angle of 20° to the axis it is at its maximum, and the subsequent decrease is still rather gradual up to angles of about 50°. There is thus no question of a strong decrease in the dosage rate over the irradiated area from the centre to the edges. On the contrary, a very uniform dosage distribution is found for not too large and

flat areas, even more uniform than with the spherical radiation diagram of normal Roentgen tubes; this is due to the fact that the larger distance from the focal spot to the off-axis parts of the field is neutralised by the initial increase in intensity as shown in Diagram 1. The phenomenon illustrated has been known for a long time, and may be explained by a consideration of the mechanism whereby roentgen rays are produced in the anode. It is not observed in normal roentgen tubes because of the relatively thick anode these tubes always contain. In the present case only the very thin foil of gold functions as an anode, and as a matter of fact KULENKAMPFF (9) was able to demonstrate the directional effect as early as in 1928 by the use of specially designed tubes with very thin anodes (see also 2, 16).

The electrons striking the anode with great velocity are slowed down on penetrating into the metal. According to the classical theory, each electron will emit radiation, continuous roentgen radiation or 'Bremsstrahlung'. According to this theory one can also expect the radiation to have zero intensity in the direction of movement of the electron, as also in the reverse direction, whereas the radiation will be at its maximum at a certain angle to this direction — depending on the electron velocity. In a thick anode a penetrating electron may repeatedly change its direction by small amounts, due to deflection by atomic nuclei, with very small loss of energy each time, before it passes a nucleus so closely that it is strongly decelerated and emits the roentgen radiation observed. The contribution by this electron to the radiation will in that case possess the directional dependence as mentioned above, but with its last direction of movement as axis. Since these axis, for all the electrons, will have a random distribution of direction, the total radiation can reveal little or nothing of the directional effect described.

On the other hand, if the anode is very thin, the electrons will pass through the entire layer with relatively few encounters with atom nuclei. The emission of each contribution to the observed radiation can therefore only be preceded by few deflections; consequently the 'axes' for all contributions deviate but slightly from the axis of the roentgen ray tube, and the total radiation will consequently also show the directional effect with but little spread.

If the anode functions as exit window, the opportunity for the natural directional effect of the radiation to be observed becomes still smaller in the case of a relatively thick anode, since the absorption effect mentioned earlier (intensity decrease with increasing angle), especially important in the case of thick anodes, is superimposed on this directional effect. Diagram 1 clearly shows the increasing importance of this effect, even with the very thin anode of the KT tube, as the tube voltage is decreased (softer radiation).

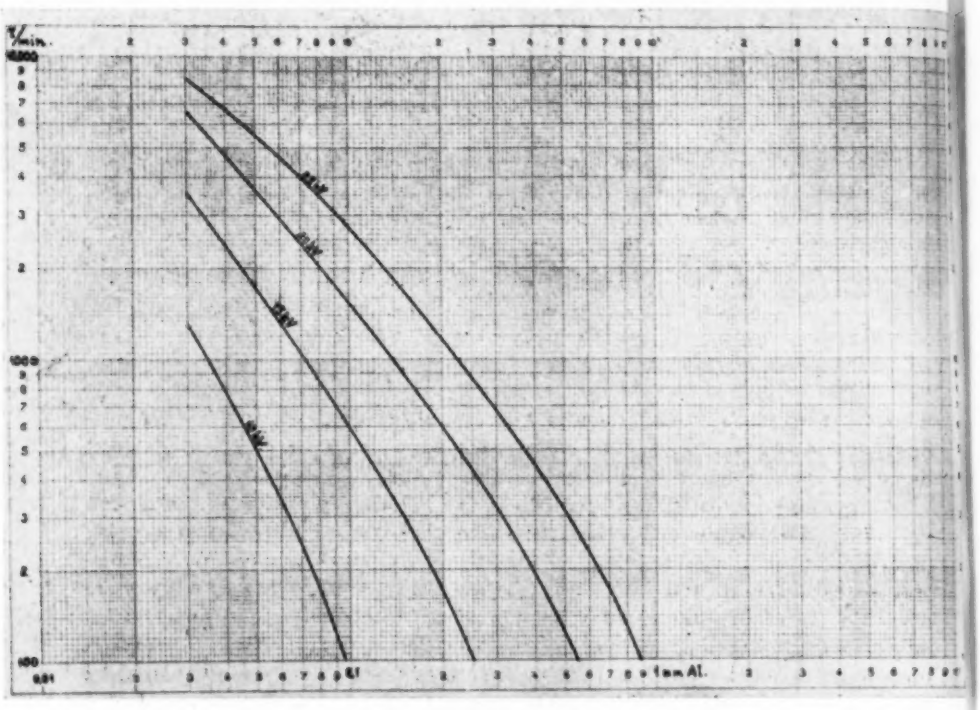
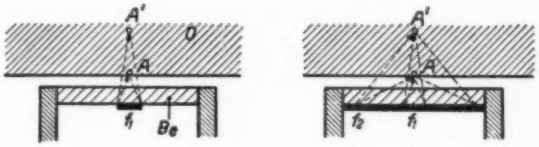


Diagram 2.

Owing to the constructional principle adopted, it is possible with the KT tube to reduce the focus-skin distance to 1 mm if so desired, viz. by pressing the anode into the surface to be irradiated. Enormous dosage rates can be realised with only very small power, if the distance between focus and object is so small. With the above-mentioned maximum permissible anode dissipation of 2.5 W and a voltage of 25 kV, the KT tube will give 8,500 roentgen units per minute at a distance of 1 cm from the focus; at 10 kV and 2 W dissipation (the tube current is 200 μA maximum), it will still give 2,600 r/min. These are measured values (Diagram 2, all curves were measured at 100 μA); a separately determined correction factor was applied for the absorption of the soft radiation in the window of the dosimeter. At a focus distance of 1 mm even much larger dosage rates, of some hundred thousands r/min., are obtained. Naturally, if the focus distance is not very small, *e. g.* 20 mm,



a. b.

Fig. 3. a) If the focus (f_1) is small, the dosage rate decreases as the inverse square of the distance. The dose thus rapidly decreases from A to, for example, A'. b) If the focus is large, the dosage rate decreases more slowly than as the inverse square of the distance. The decrease is intensified, however, by the extra absorption of oblique rays in the object 0: point A' profits less from the size of the focus than point A, since the rays originating from f_2 have to travel a longer distance in the tissue than those originating from f_1.

which can also be reached with the CT tube, the KT tube is, as far as dosage rates are concerned, by far inferior to the CT tube, which was designed for a maximum power of 100 W and voltages of up to 50kV.

In normal roentgen therapy tubes the focus is made as small as possible in order to obtain a sharp boundary to the field to be irradiated (small penumbra width of diagram edges); in the KT tube, on the contrary the electrode configuration was so designed as to spread the focus over the entire anode surface (diameter 6.5 mm). Owing to the rather large focal dimensions the loading of 2.5 W is permissible and the above-mentioned very large dosage rates are obtained. It is true that part of the gain with regard to the depth penetration, obtained by the selected

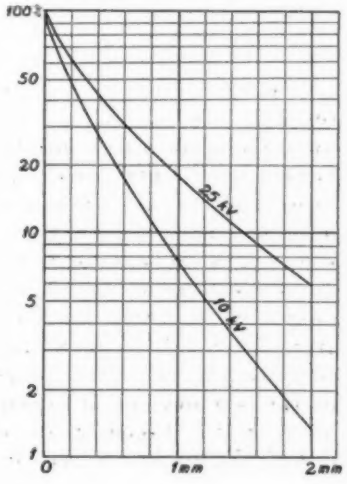


Diagram 3. Dosage rate of the KT tube computed for various depths in the irradiated body at a focus—skin distance of 1 mm, for two different tube voltages. The dosage rate on the skin was set equal to 100 for both curves.

principle of construction, is sacrificed if the focus is so large; if the focus is not small in proportion to the focus-skin distance, the dosage will, for geometric reasons, not follow the inverse square law, but will decrease much more slowly with increasing distance.

Thus, the dosage rate at 1 mm distance will not be 100 times larger but, according to our computation, only 25 times as large as at 1 cm distance.

Still, one can see from these figures that the distance effect is still considerable. Moreover, it is enhanced by the effect of the absorption of the rays in the tissue: points at some distance below the skin surface profit less by the largeness of the focus, therefore, than do points on the skin surface (Fig. 3). The resulting decrease of the dosage with depth is shown in Diagram 3. It will be seen that only a thin layer of skin of a few tenths of one millimetre is consequently effectively irradiated.

Treatment of the animal cornea

The dosages in roentgen treatment are very diversely set out in the literature. So-called "fractioning" of the doses is applied and generally a succession of small doses is administered. We made a few experiments with rabbits' eyes.

A. 11 rabbits' eyes were treated with several rather high doses, from 4,000 r to 30,000 r, in order to determine the resistance of the cornea. As it is important not to injure the deeper parts of the eye when high doses are given, the experiments were conducted with the Lilliput roentgen tube. The technique with 25 kV, a filter of 0.5 mm Be, and a F. S. D. of 1 cm (H. V. L. 0.06 mm Al), offered great safety. All treatments were 4 × fractioned in 2 weeks. The eyes were studied at least twice a week through a slitlamp over a period of 4 to 8 months.

Up to 30,000 r no fatal effects occurred and on final examination the cornea remained clear.

B. As individual sensitiveness may occur 20 eyes were treated with 16,000 r, a dose 10 times as great as the clinical one generally used by us. None of these corneae showed changes, neither through the slitlamp nor in the histologically prepared slides. Observation time 4—8 months.

C. When higher doses of from 30,000 r up to 50,000 r, were given, peculiar differences revealed themselves: conjunctivitis, deposits of brown pigment in the corneal epithelioma and deeper turbidity and vascularisation of the cornea. The histologic examination also showed differences: degeneration of the epithelium and cellular infiltrations into the stroma being remarkable for the number of eosinophile granulocytes present; these were lying nearly everywhere in the stroma and even between the cells of the epithelium. They were often seen very near to small blood vessels. They seemed to originate from the blood in these capillaries; so large a number of eosinophile granulocytes is seldom encountered in the cornea. They probably indicate an allergic reaction, caused by the roentgen rays. (Fig. 4.)

The experiments were carried out upon 8 rabbits' eyes; the observation time was mostly 8 months.

D. Finally 6 rabbits' eyes were treated with an equally large dose as in the group of 20 eyes (B) *i. e.* 4 × 4,000 r but with the 50 kV Philips Contact set, a 'Philite' filter (about 0.5 mm Al) and 2 cm F. S. D. (H. V. L. 0.37 mm Al).

As was to be expected the cornea showed no irregularities but after 3 months all the eyes showed a diffuse cataract. Observation time: 6 months.

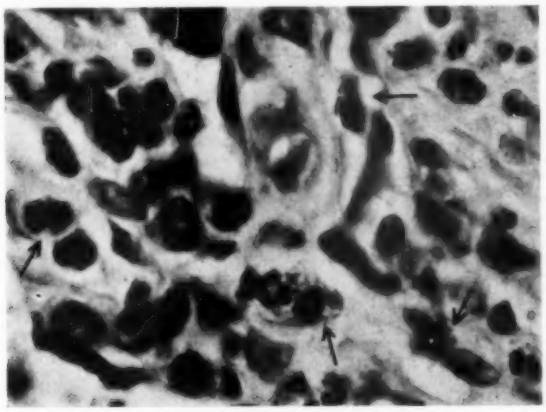


Fig. 4. Many eosinophile granulocytes around a small capillary.

This experiment indicates the great danger of treating the cornea with larger doses when apparatus of higher voltage, or a more penetrating beam, is used.

We concluded that the cornea can resist a very high dose of roentgen radiation.

E. One of the most important points in treatment is the vascularisation of the transplanted cornea, concerning which some experiments were also made.

An injection of lYE (0.4 cc NAOH 0.15 N) into the cornea of rabbits produced an artificial macula on the upper part 2 mm from the limbus. These maculae were considerably vascularised after 12 to 14 days. 16 eyes were treated in this way. After a fortnight, *i. e.* when the vascularisation was at its climax, 4 of these eyes were treated with 4 × 800 r (Lilliput 25 kV set). 5 eyes were kept as controls and were not treated. Furthermore, 3 eyes were treated with 4 × 400 r, 4 × 200 r and 4 × 400 r respectively, also at the climax of vascularisation.

It appeared that in the treated cornea the ingrowth of the vessels receded at a quicker rate than in the controls. 4 corneae were treated before the climax of vascularisation had been reached. In these cases, 'ingrowing vessels' were not prevented but proceeded in the same way as in the controls. In order to make things clear the results are represented in Diagram 4. (The horizontal lines represent time; the perpendicular ones the condition of the ingrowing vessels.)

The condition is divided into 5 stages:

0 = no vessels
1 = some deep vessels
2 = some deep vessels + surface vessels
3 = a moderate number of deep + surface vessels
4 = a great many deep + surface vessels.

The diagram showes the mean of the controls and the mean of all the treated cases. Furthermore, the mean of the group treated with 4 × 800 r (curve 1 + 2) were also included. When the higher doses (4 × 800 r and 4 × 1,000 r) were given, a considerable recession began as early as after 4 weeks, but after 8 weeks a slight relapse occurred.

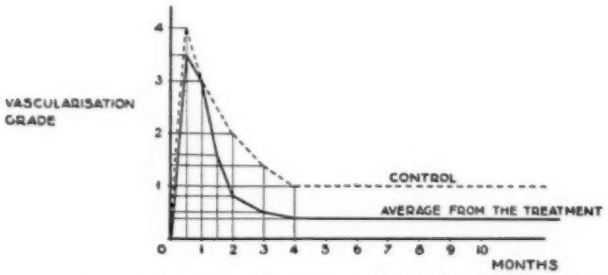


Diagram 4. Treatment of the eyes of rabbits after injection of O.IN NaOH.

In summarising the results we find that with the treated cornea the vessels had with a single exception disappeared after 6 weeks, whereas in a group of controls this occurred only after 14 weeks.

Early treatment offers no advantage at the climax of vascularisation. Doses of from 800 to 4,000 r fractioned into 4 × within 2 weeks proved effective.

Conclusions. 1. Roentgen therapy is an important gain in fighting vascularisation:

a) If the vessels continue to exist for a long period there is a very great chance of permanent 'turbidity' of the cornea.

b) If the ingrowing vessels can rapidly be made to disappear, the chances of a clear transplantation are far better.

2. Treatment at a very early stage (*i. e.* a short time after the transplantation of the cornea), is unnecessary, hence undesirable. The ingrowing process may possibly be injured and vascularisation is then not more effectively overcome or stopped.

b. Treatment of the human cornea with soft roentgen radiation

Clinical experiences. Since 1940 we have regularly been using roentgen rays to combat vascularisation of transplanted corneae. Even some

years before 1948 roentgen rays were used for other afflictions of the cornea. In all, 100 cases were treated: 10 of keratitis (Group 1) and 90 of vascularsation of transplanted corneae (Groups 2—7). (Table 1.)

Table I

The clinical groups are placed together here. On the right, the average results of the condition of vascularisation before treatment, and 1, 3 and 6 months after treatment, in figures.

Treatment of the human cornea with soft roentgen radiation (clinical experiences).

Group	Apparatus	Dosage	Condition of vascularisation				
			before treatment	after 1 month	after 3 months	after 6 months	Number of patients
1. Keratitis	25 kV	200—3,000 r	3.0	—	—	1.6	10
2. Cornea transpl.	50 kV	360—1,500 r	2.0	2.1	2.0	1.9	17
3. » »	25 kV Old app.	300—1,600 r	2.6	1.7	1.5	1.3	15
4. » »	25 kV Lilliput	400—3,400 r	3.0	2.1	1.9	1.9	18
5. » »	Lilliput + cortisone	800—3,300 r	3.0	2.2	2.1	2.1	10
6. » »	50 kV (Dr. JANSEN)	200—1,600 r	2.6	1.4	1.4	1.4	30
7. » »	Cortisone		2.2	1.3	1.3	1.3	20

The cases of vascularisation of transplanted corneae were arranged in accordance with the set used. In the Roentgen Therapy Clinic of the University Hospital, Leiden, Group 2 was treated with a 50 kV set (H. V. L. 0.37 Al), Group 3 with a 25 kV set (H. V. L. 0.06 Al) and Group 4 with the 25 kV set with the Lilliput roentgen tube. Group 5 was treated with roentgen radiation combined with the local application of cortisone. At St. Elizabeth Hospital, Leiden, Group 6 was treated by A. G. M. JANSEN with a 50 kV set (H. V. L. 0.37 Al), tangential fields being employed. The doses varied from 200 to 3,300 r. A higher dose was given for a more serious affliction.

Practically all treatments were fractioned into 4 spread over two weeks. For comparison purposes a group of vascularisation of the transplanted corneae (Group 7), which had only been treated locally with cortisone (1 drop 0.5 % twice a day for 2 weeks) was included.

In order that the survey of the results of treatments should be clear, the condition of the vascularisation was divided into 4 categories:

3 = a great many deep + surface vessels.
2 = a moderate number of deep and surface vessels.
1 = a single (either deep or surface) vessel.
0 = no vessels.

Table 1 shows the average results of the different groups in figures. The condition mentioned: before treatment, 1, 3 and 6 months respec-

tively after treatment. A diagram was made to show the results more clearly (Diagram 5).

Conclusions. In most of the majority of cases a definite improvement can be noticed within a month.

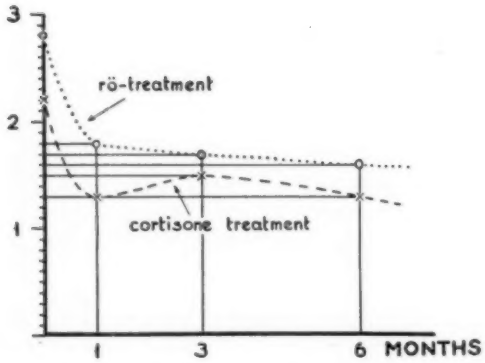


Diagram 5. Results with 100 patients.

Fig. 5.

In the 'keratitis' group, tuberculous keratitis and the torpide ulcers showed best reactions.

Even in very unfavourable cases the condition was improved. As could be expected, the different apparatuses used gave more or less the same results.

Yet the Lilliput roentgen tube apparatus seems to us to be a great improvement due to the small size of the tube rendering it easy to handle and the rays to be properly localised (Fig. 5). The localisation can even be improved by using applicators having different shapes adapted to the objects to be treated. Moreover, this set gives a greater degree of safety when treating the deeper parts of the eye; this was determined in experiments on the eyes of rabbits. Approximately similar results were obtained even when widely divergent doses were administered. The same results were obtained in serious cases but the doses used were much higher.

Two patients were treated before the transplantation of the cornea, as vascularisation could be expected after the operation. A short time after the operation, however, serious ingrowing set in and was not easy to curb by treatment.

The simultaneous treatment with roentgen radiation and cortisone did not seem to render any better results.

On the whole the 'favourable' cases responded in a better way than those revealing very severe vascularisation.

The results of cortisone treatment at first sight appear to be very satisfactory, but this group consisted of more favourable cases than the other groups and there were a number of recurrences.

We came across cases that reacted well to roentgen therapy but not to cortisone.

Both in the field of 'keratitis' and of vascularisation of the transplanted cornea roentgen contact therapy gave hopeful results. A great many possibilities are still open which we hope we shall be able to investigate later on, after gaining a wider range of experience from the treatment of human subjects.

SUMMARY

A description is given of a new Lilliput roentgen tube energized at a potential of 25 kV and the basic principles of its design are discussed. Certain experiments carried out on the cornea of rabbits are reported and the results of treatment of the human cornea with a 50 kV set, a 25 kV set and the latter combined with the new tube are presented and commented upon. Both in 'keratitis' and vascularisation of transplanted cornea, the results appeared to be most promising.

ZUSAMMENFASSUNG

Eine neue Lilliput-Röntgenröhre (25 KV) wird beschrieben und die Grundprinzipien ihrer Anwendungsmöglichkeiten werden diskutiert. Gewisse an der Kaninchencornea vorgenommenen Experimente werden berichtet und die Ergebnisse der Behandlung der menschlichen Hornhaut mit einer 50 KV-Apparatur, einer 25 KV-Maschine sowie letztere kombiniert mit der neuen Röhre werden vorgelegt und kommentiert. Sowohl in Fällen mit »Keratitis« als auch bei der Vaskularisation der transplantierten Cornea scheinen die Ergebnisse sehr Gutes zu versprechen.

RÉSUMÉ

Les auteurs décrivent un nouveau tube roentgenthérapique «lilliputien» fonctionnant sous une tension de 25 kV et étudient les principes fondamentaux de sa conception. Ils rapportent certaines expériences effectuées sur la cornée du lapin et présentent et commentent les résultats de traitements de la cornée humaine faits avec un appareillage à 50 kV, un à 25 kV, et ce dernier équipé avec le nouveau tube. Les résultats semblent être très prometteurs aussi bien dans la «kératite» que dans la vascularisation de la cornée transplantée.

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A SIMPLE DEVICE FOR ADJUSTMENT OF THE SKIN DISTANCE FOR IN VIVO MEASUREMENTS OF RADIOACTIVE ISOTOPES

by

Lars Jonsson

For *in vivo* measurements of γ-irradiating isotopes a definite distance between the measuring instrument (scintillation crystal or G.-M. tube) and the skin surface is often wanted. The estimation of I^{131} uptake in the thyroid is a common example of this type of measurement. The distance may be adjusted by a measuring tape or by a 'beam director' of the same type as often used for roentgen therapy. The following device is, however, more convenient especially when routine measurements on a large scale are performed.

The arrangement is illustrated in Fig. 1 a. Two similar optical systems are fixed on the measuring instrument and give rise to two cross-shaped beams. The beams intersect with a relatively wide angle and the intersection is adjusted to the required distance from the crystal or the tube. In adjustment of the distance to the skin surface, the two crosses coincide when the correct distance is obtained (Fig. 1 b), while a slight deviation gives rise to a double picture (Fig. 1 c). When a distance of 30 cm is used the error is less than $\pm$ 2 mm or less than 1 per cent. (The real error in the distance is of course larger due to the fact that the true distance from the source, for instance the thyroid, to the skin is not exactly known.) The optical system is constructed in the following way. A light beam from a small lamp passes through a cross-shaped slot and a lens, which gives a sharp image of the slot at the point of intersection. This arrangement

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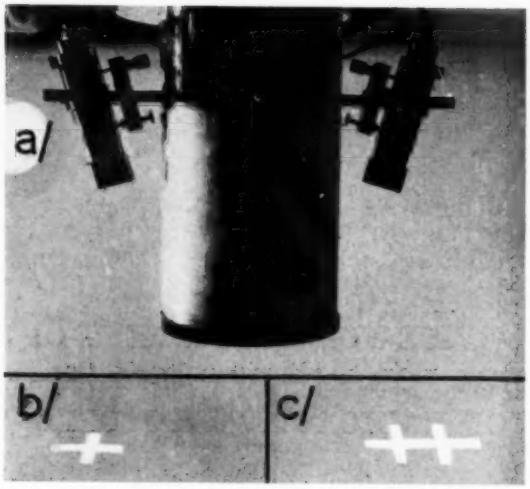

Fig. 1. Scintillation counter with the optical arrangement described for adjustment of the skin distance.

makes a rapid and accurate adjustment of the skin distance possible, which facilitates routine work especially in thyroid measurements. The device has worked satisfactory for more than one year at our isotope laboratory.

BOOK REVIEWS

ROENTGEN EXAMINATION OF THE PROXIMAL FEMUR END IN CHILDREN AND ADOLESCENTS. A standardized technique also suitable for determination of the collum-, anteversion- and epiphyseal angles. A study of slipped epiphysis and coxa plana. By Lars Billing, 80 pages, 23 illustrations. Acta radiol. Suppl. 110. Stockholm 1954. Swed. Kr. 25: —.

The collum angle or angle of the neck and the anteversion angle are defined. It is important to determine these angles in order to diagnose a coxa vara or valga and a coxa retroverta or anteverta; this is particularly necessary if correction osteotomy is planned. The measurements are also of importance in deciding whether and how additional roentgenograms should be obtained in order to solve a special problem. The author has worked out a roentgen technique (two films obtained with a vertical projection) which has the following advantages:

1. The positioning for both views is easy to perform even in the presence of a moderate degree of limitation of movement of the hip-joint. Exact positioning may be performed which means that almost identical projections may be obtained on re-examination, even if carried out by different radiographers.

2. The collum- and anteversion angles may be calculated with the help of a nomogram.

3. In children and adolescents, pathologic processes are generally localized to the epiphysis or epiphyseal cartilage; and it is only when the epiphyseal cartilage lies fairly vertically during the exposure that the resultant films will be satisfactory for the assessment of changes. The standard projections are so selected that both the frontal (a-p) and the lateral views are suitable for diagnostic examination if the anatomy with reference to the anteversion angle and the plane of the epiphyseal cartilage do not lie in a plane too divergent from the standard.

4. If such an anatomic divergence should exist, diagnostically suitable projections may be gauged from the two standard projections and precise directions given for carrying them out.

The author calls the plane in which both the diaphyseal and the collum axis lie the 'anteversion plane'. He shows in a standard material that the plane of the epiphyseal cartilage lies at right angles to the anteversion plane, and calls the angle between these planes the 'epiphyseal angle', which is hence 90°. A simple method for the determination of this angle is given.

In a *slipped capital femoral epiphysis*, the epiphysis slips for the most part backwards and the epiphyseal angle becomes less than 90°. The author shows that this angle is a practical measure of the degree of slipping. The determination of the epiphyseal angle affords a more definite diagnosis of a slight degree of slipping than was previously possible, and permits the demonstration of a pre-slipping stage. The epiphyseal angle even in the sign-free contra-lateral hip-joint is found to be generally less than normal. In the operation of epiphysiodesis ('nailing in situ'), the author employs a simple roentgen technique which furnishes exact information regarding the position of the point of the nail in the head.

In the roentgen investigation of coxa plana, the standard projections of the author produce films which are in every way comparable and of considerable value in the re-examinations. In the literature it is recommended that the deformity of the head should be indicated by the index *height of the epiphysis/the breadth of the epiphysis*, obtained by roentgenographic mensuration. The author shows that this index value is markedly dependent on the projection from which the measurement is made. The projection used must therefore be indicated precisely.

Autoreview.

MEMORANDUM ON GAMMA-RAY SOURCES. Second Edition. The Institute of Physics. London 1954. 28 pages. £ 0.3.6.

The work is a modernisation and extension of the edition published in 1952. It contains physical characteristics of gamma-ray sources for radiography and gives information of importance in industrial radiography: the radiographic technique, protection of personnel and costs.

Erik Lindgren.

DIE GESUNDE UND DIE KRANKE WIRBELSÄULE IN RÖNTGENBILD UND KLINIK. PATHOLOGISCH-ANATOMISCHE UNTERSUCHUNGEN. Von G. Schmorl †. Für Röntgenkunde und Klinik bearbeitet von H. Junghanns. 3. erg. Auflage. 304 S., 403 Abb. Georg Thieme Verlag, Stuttgart 1953. DM 72.—.

New conceptions of degeneration and of herniation of the intervertebral discs have been included. This book is still indispensable to those who wish to enter deeply into the roentgenology of the spine.

Åke Lindbom.

DIE ANGIOGRAPHIE ZUR ERKENNUNG, BEHANDLUNG UND BEGUTACHTUNG PERIPHERER DURCHBLUTUNGSSTÖRUNGEN. Von H. W. Pässler. 115 S., 102 Abb. Georg Thieme Verlag, Stuttgart 1952. DM 29.70.

This book contains really beautiful angiograms of the abdomen and the lower limb, extremely well reproduced as always by Thieme. The author possesses a great experience of peripheral vascular diseases but expresses many opinions upon angiologic matters which are not always well founded. The contents of the book are considerably more comprehensive than the title.

Åke Lindbom.